

# **Niobrara Production from the Lowry-Bombing Range Area Denver Basin, a Deep-Basin, Paleostructural Trap**

**Stephen A. Sonnenberg<sup>1</sup>**

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## **Abstract**

The Lowry-Bombing Range (LBR) field (Arapahoe County, CO) is productive from the Niobrara B and C chalks at vertical depths of 7300 to 7950 ft. Both the Niobrara B and C chalk beds range in thickness from 20 to 30 ft in the field area. Porosities in the B chalk range from 10 to 12%; porosities in the C chalk are approximately 10%. The LBR field is being developed by horizontal drilling.

Resistivity mapping in the Niobrara chalks show anomalously high resistivities in areas of Niobrara production. The high resistivities (> 50 ohms) are due to hydrocarbon accumulation/charge in the chalk beds. The high resistivities also coincide with mapped high vitrinite reflectance ( $R_o > 0.8$ ) and high bottom hole temperatures on well logs (geothermal gradient 1.9 to 2.5°F/100 ft).

The total Niobrara is thin in the LBR compared to surrounding areas and averages approximately 350 ft. Thinning occurs in the Niobrara A marl across the area. This thinning is interpreted to be due a paleostructure high being present in the LBR area. Paleostructure also appears to influence thicknesses in lower Cretaceous strata. This paleostructural feature is herein named the LBR High. The paleostructure trends W NW across the area and is approximately 25 miles wide and 60 miles in length. Present day structure in the LBR is primarily due to the Laramide orogeny. Regional dip is to the west across the LBR area.

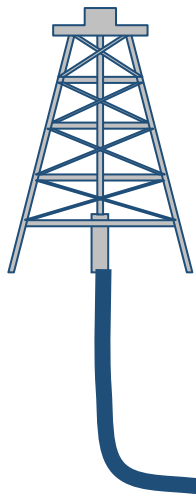
The marls between the chalk beds are regarded as source beds for oil found in the chalk beds. Source rock TOC and Tmax data for the Niobrara in LBR is as follows: A marl, 2-3.4 wt.%, 445°C; B marl, 2.58-3.74 wt.%, 445°C; C marl, 3.5-6.27 wt.%, 451°C; D marl, 0.8 wt.%, 450°C. Source rock data for the Carlile is TOC 1.5-2.2 wt.% and Tmax 453°C. The overlying Sharon Springs source bed has TOCs ranging from 2.5-4.0 wt.%. Thus, the Sharon Springs, Niobrara, and Carlile have good source rocks (> 2 wt.%).

Production from horizontal wells is variable and ranges from 199 to 1613 BOPD. The best production is from longer reach laterals drilled in an east west direction (~2 mile laterals). Maximum horizontal stress direction is interpreted to be NW SE.

## Summary

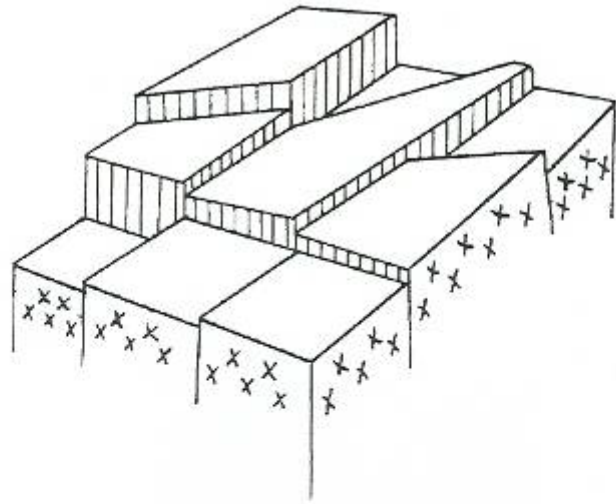
- L-BR PaleostuctureMost unconventional Niobrara production located on paleostructures
  - Thinning in Niobrara, J SS
  - Lower Paleozoic thickness patterns
- L-BR is thermal anomaly ( $T_{max}$  &  $R_o$ )
- Niobrara B and C resistivity anomalies (= accumulation)
- Horizontal targets: A, B2, C chalk intervals
  - Highest P&P: A & B2 chalks
  - Chalky (coccolith) porosity: interparticle, intraparticle, intercrystalline
- Niobrara source beds: A, B, C marls (Type II)

# Niobrara Production from the Lowry-Bombing Range Area Denver Basin, a Deep-Basin, Paleostuctural Trap

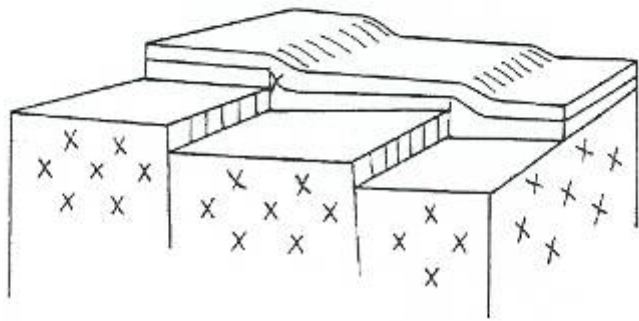


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PI MUDTOC Consortium  
Colorado School of Mines

# Intrabasin Tectonic Control on Sedimentation



Basement: mosaic of fault blocks

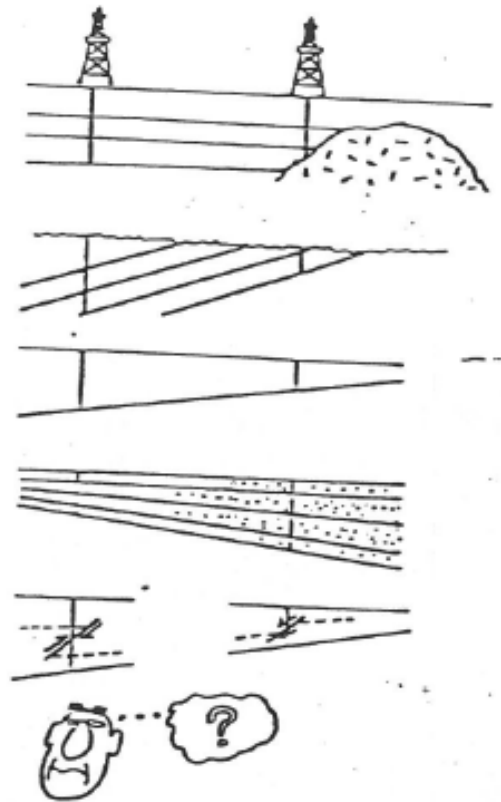


Recurrent movement on fault blocks

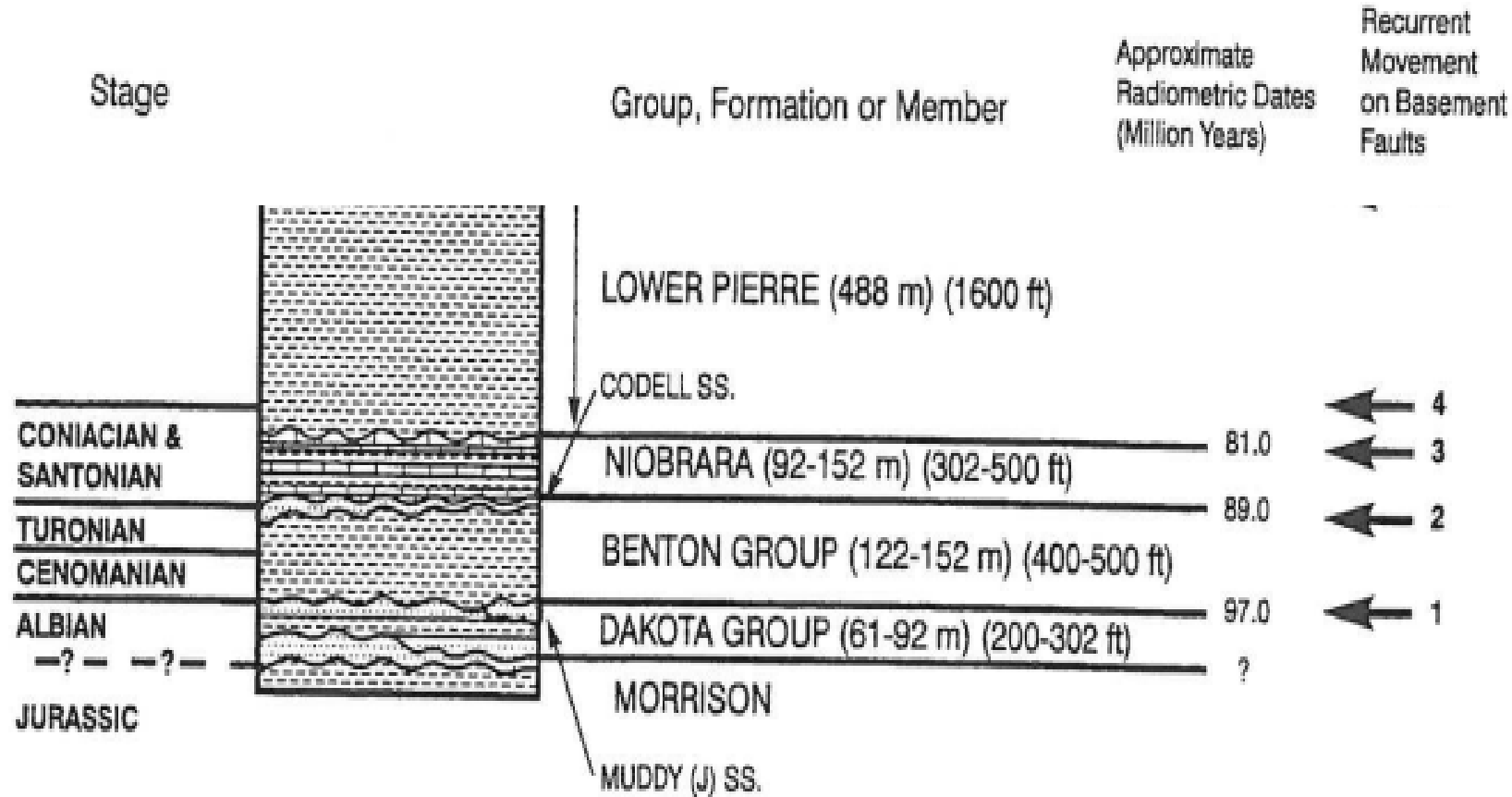
## Thicks and Thins & Paleostucture

### THICKS AND THINS

1. ONLAP
2. OFFLAP AND/OR EROSION
3. CONVERGENCE
4. COMPACTION
5. FAULTING
6. ERRORS

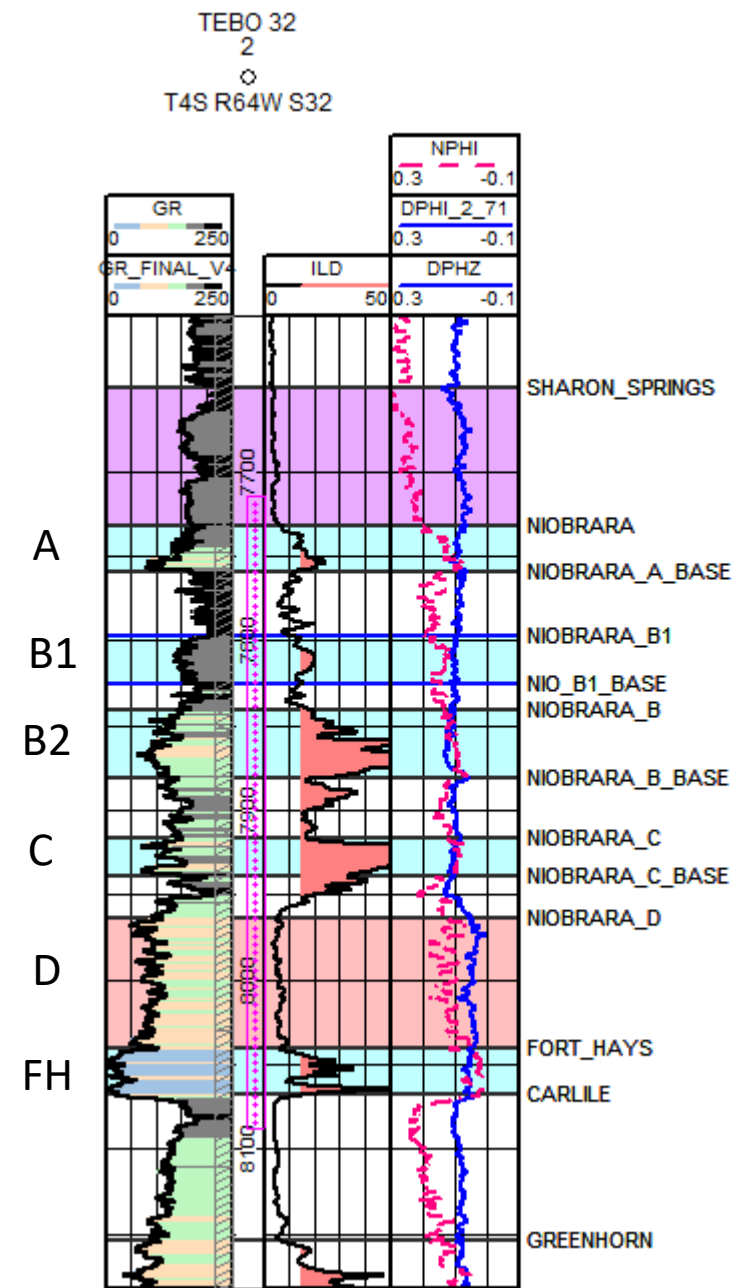
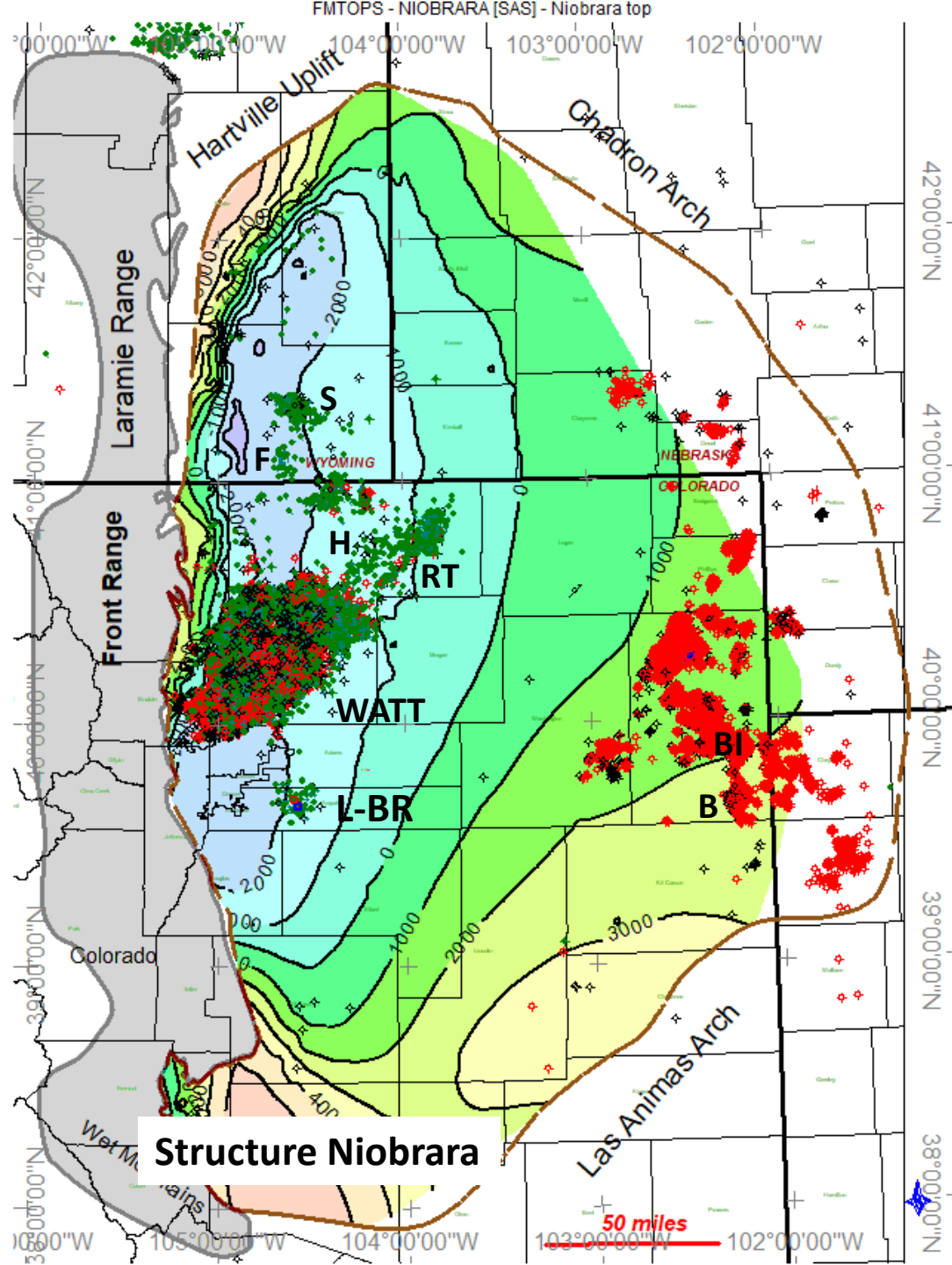


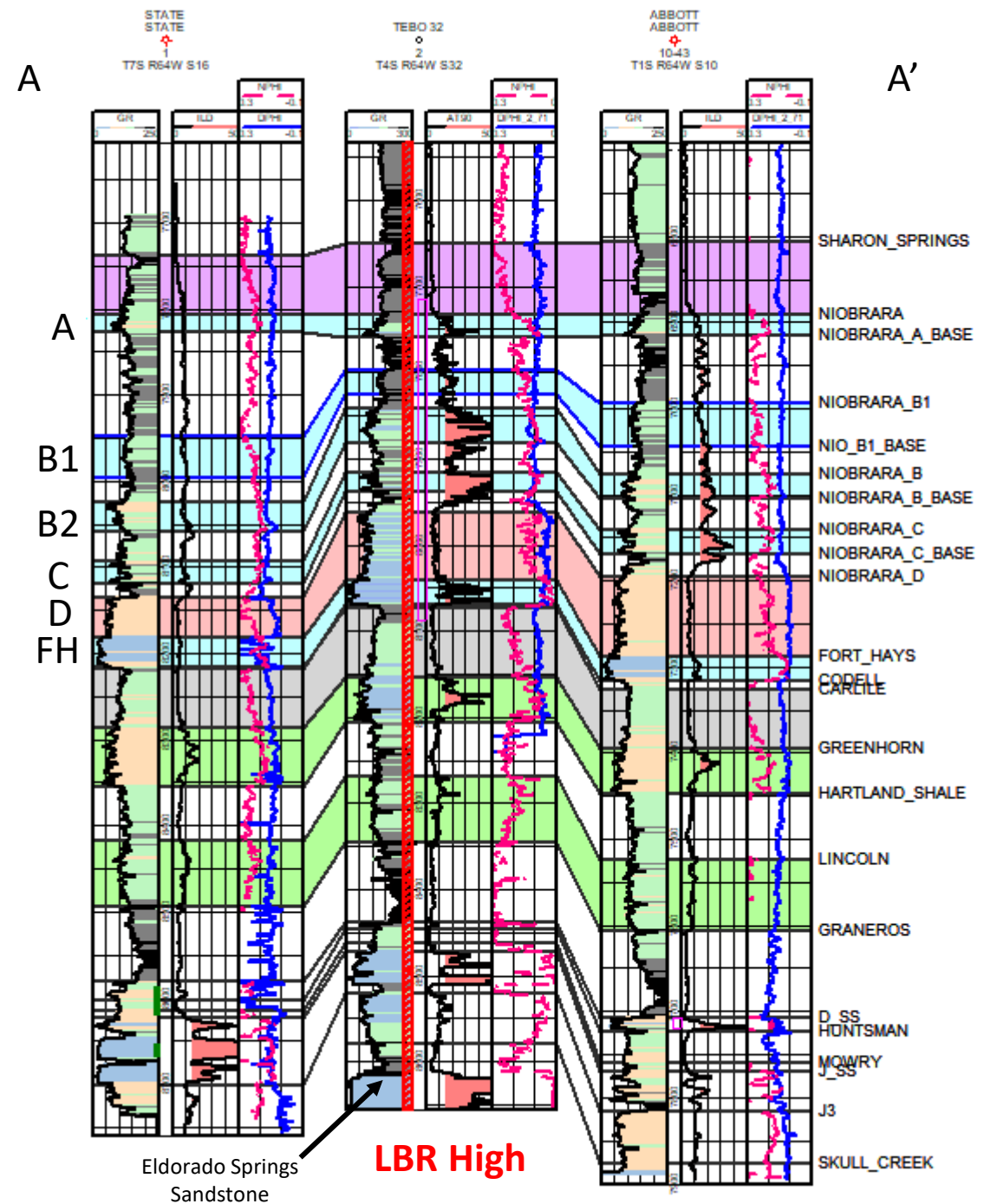
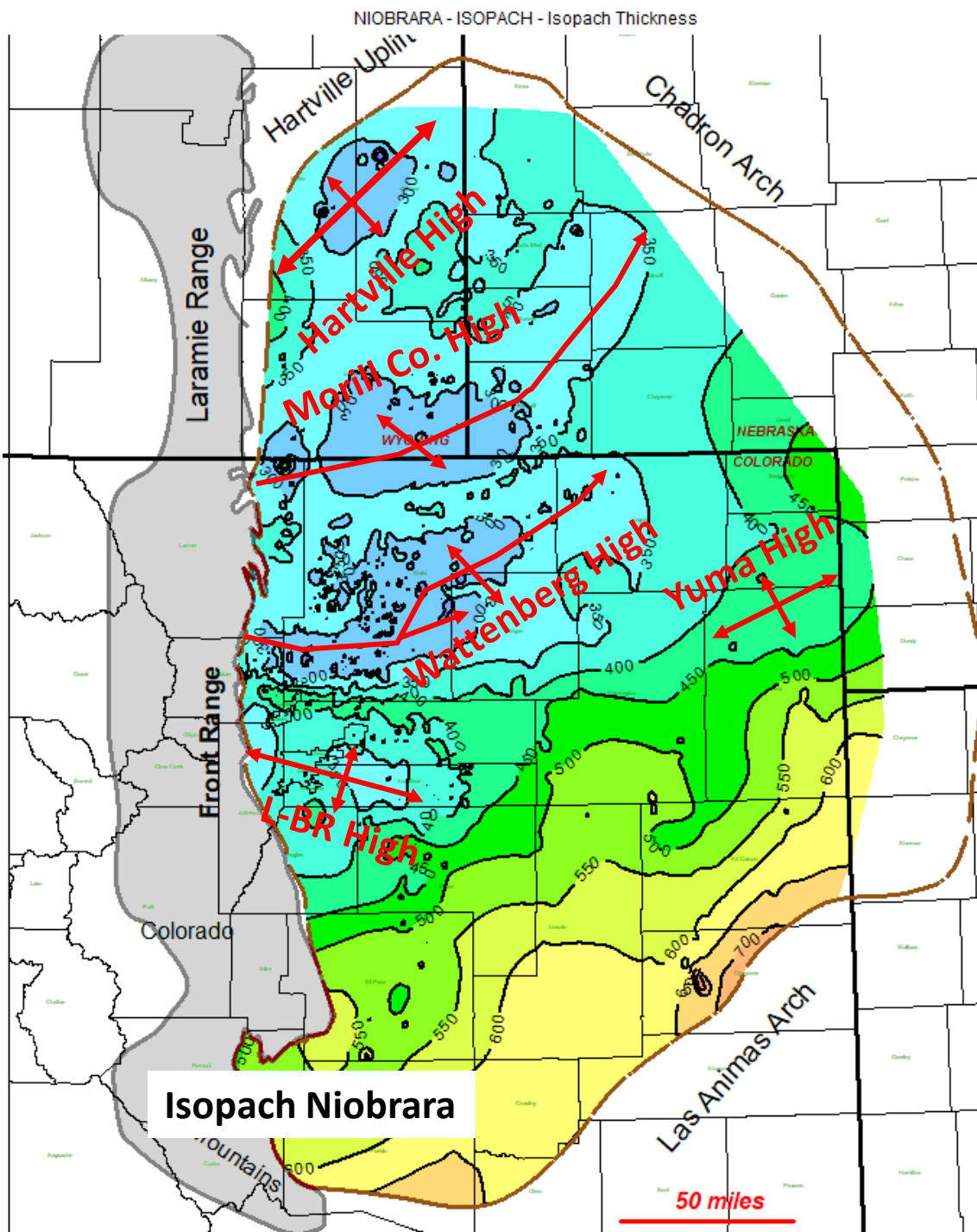
## Recurrent Movement on Basement Fault Systems “Intrabasin Tectonic Control on Sedimentation”

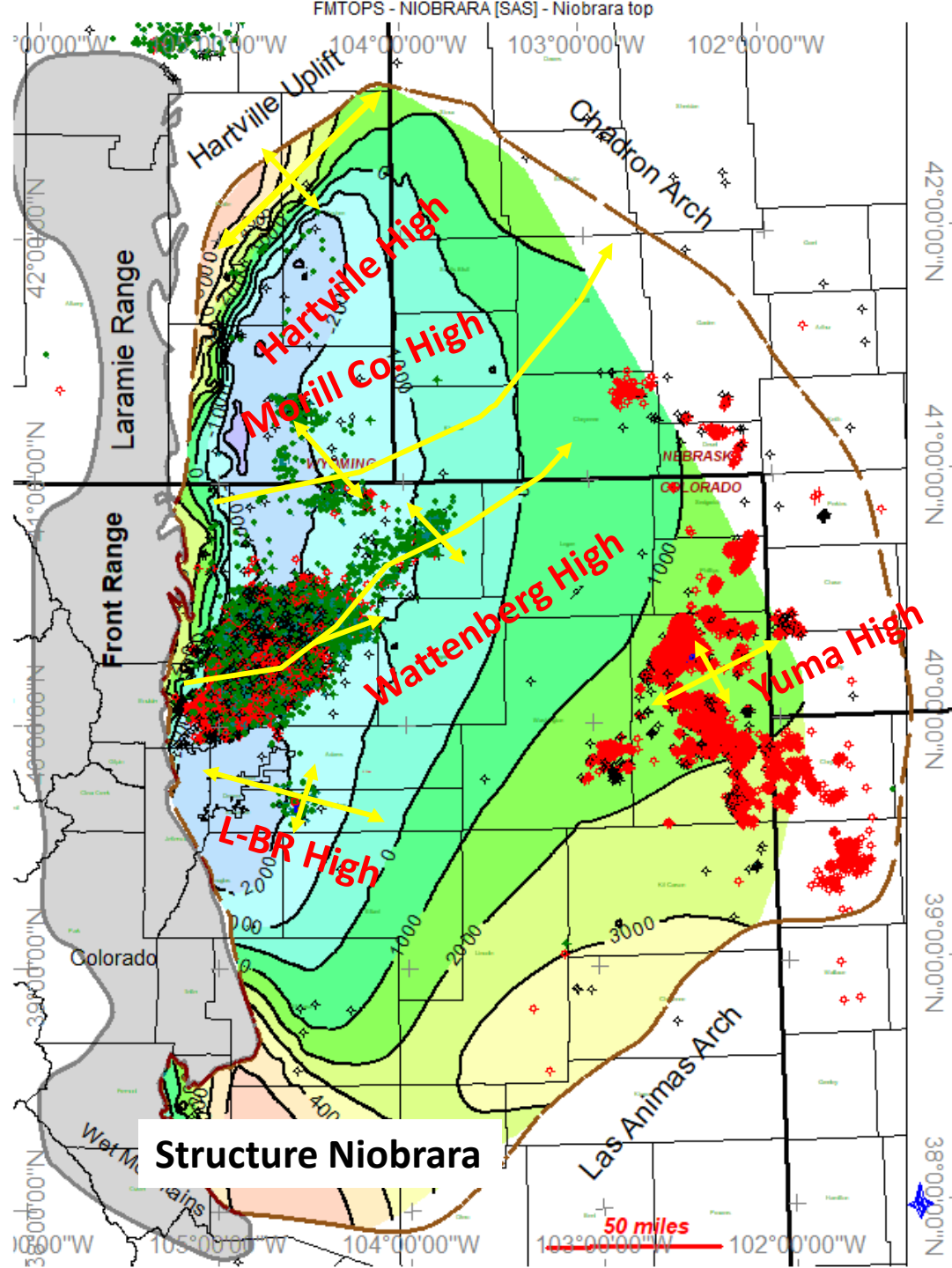


Modified from Weimer, 1996









## Niobrara Production associated with paleostructural highs

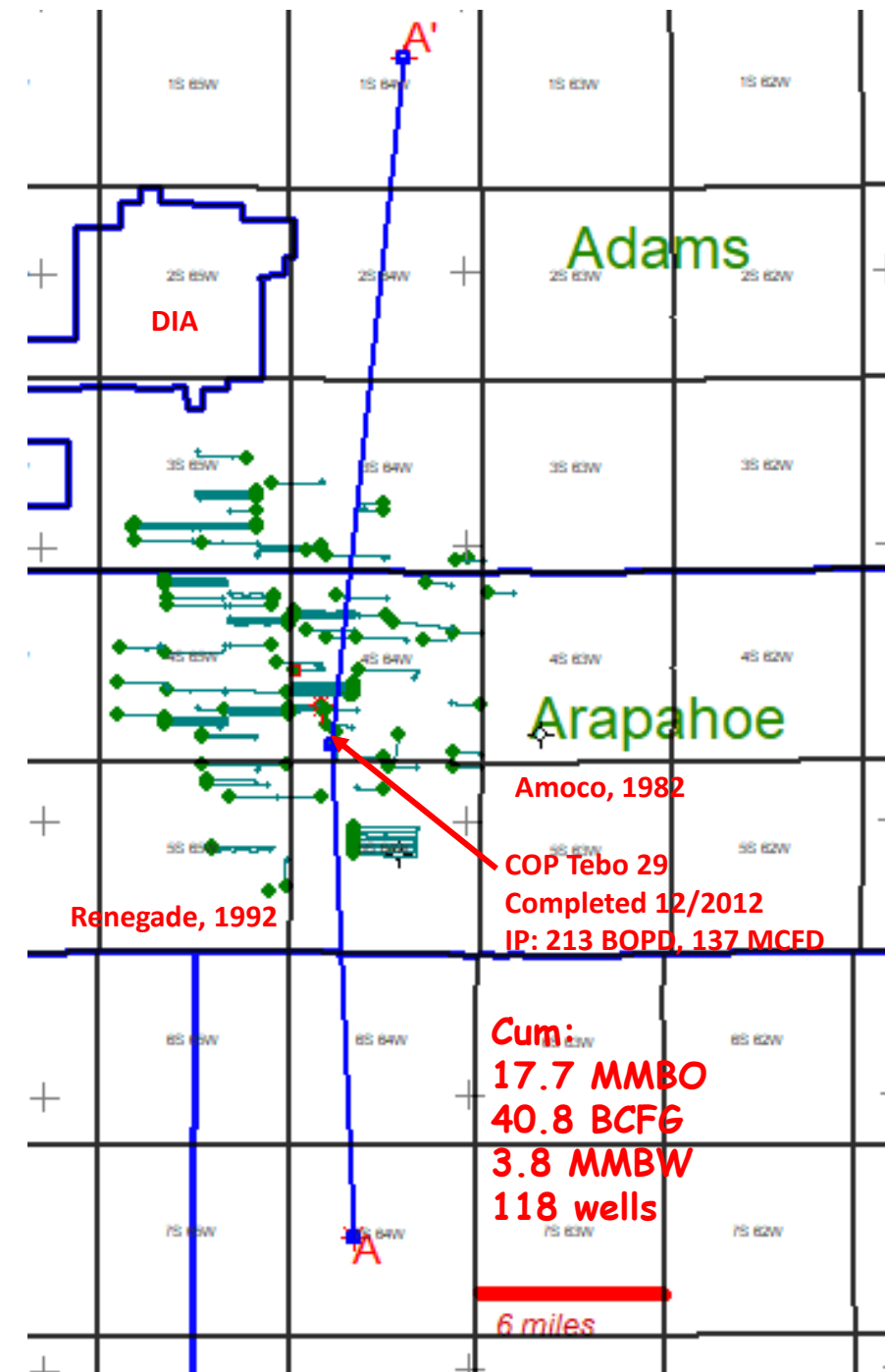
High heat flow along fault systems or intrusive bodies

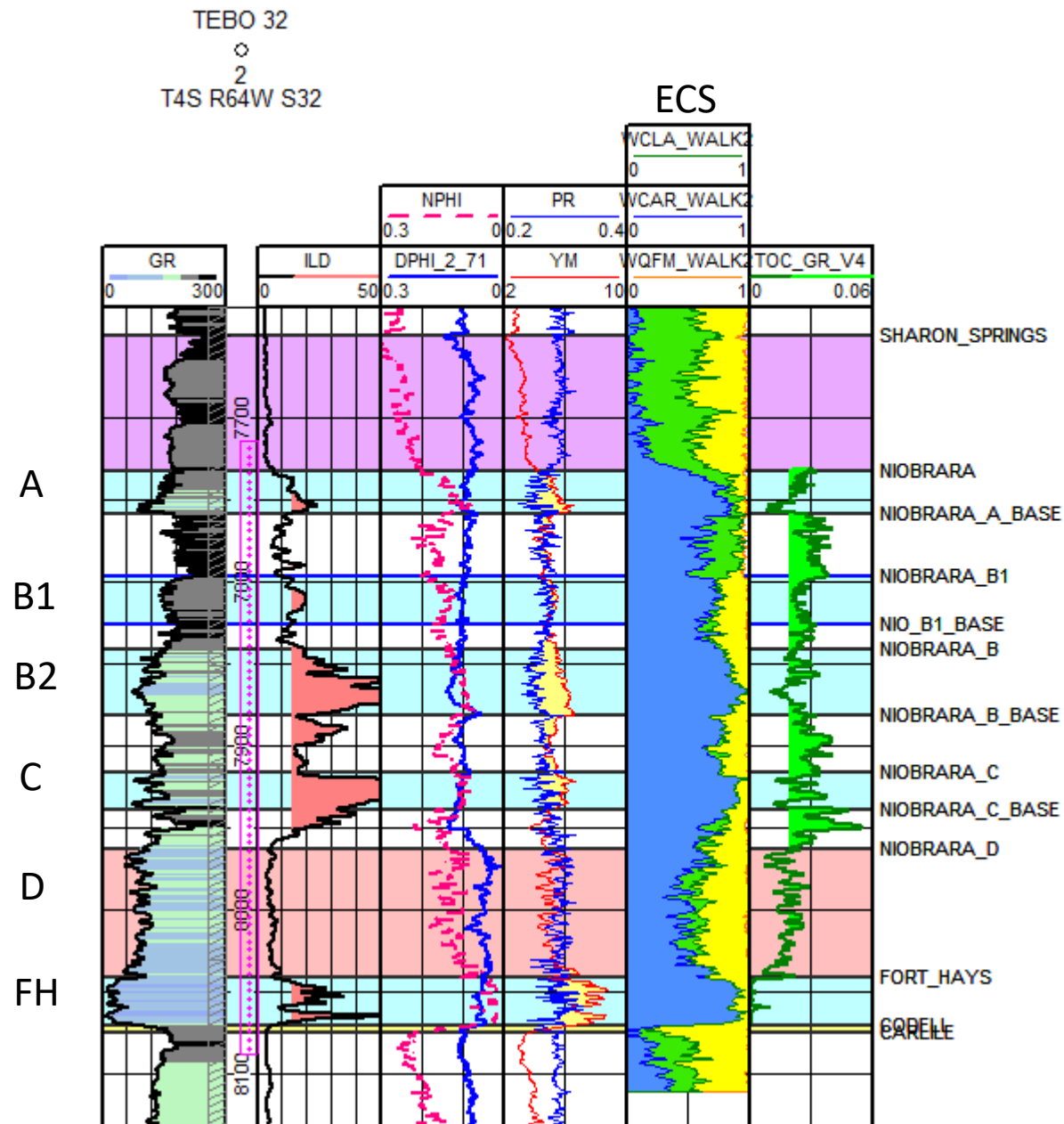
Higher heat conduction associated with Niobrara thins thus higher thermal maturity

More heat insolation associated with Niobrara thicks thus lower thermal maturity

# Lowry-Bombing Range Niobrara Field

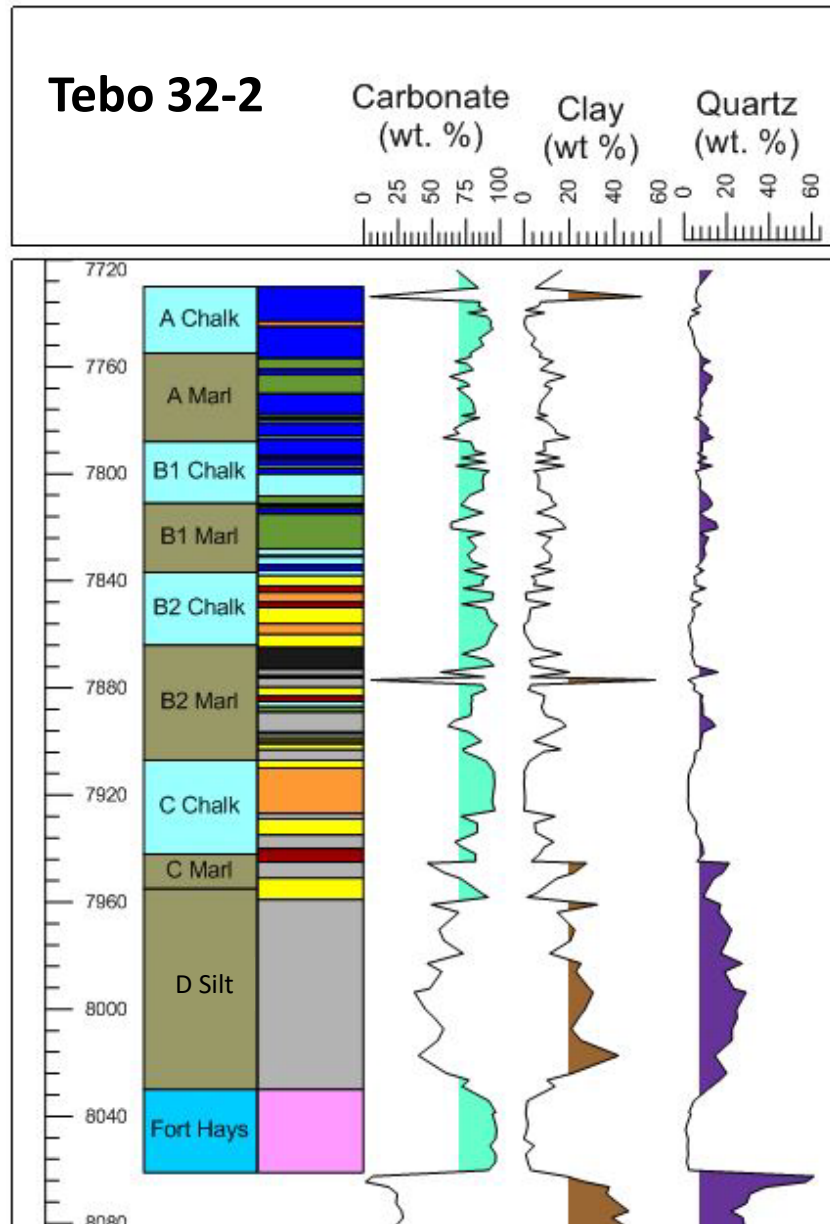
- **Depth: 7732 -- 8071 ft (vertical)**
- **Thickness:**
  - Niobrara – 340 ft
  - A chalk – 27 ft
  - A marl – 38 ft
  - B1 chalk – 29 ft
  - B1 marl – 15 ft
  - **B2 chalk – 40 ft**
  - B2 marl – 35 ft
  - **C chalk – 23 ft**
  - C marl – 24 ft
  - D marl/chalk – 78 ft
  - Fort Hays – 30 ft
  - Codell – 1 ft
- **Porosity: Niobrara 10-13%**
- **Permeability: < 0.1 md**
- **GOR: 650 scf/bbl**
- **Gravity: 38 deg. API**
- **Tmax: 445°C**
- **Ro: 0.8-0.9%**
- **Pressure gradient: 0.6 psi/ft**
- ConocoPhillips leases 21,048 contiguous acres from CO Land Board \$137 million, January 2012
- Also acquired acreage from Anadarko
- Horizontal discoveries in 2012
- Older uneconomic Niobrara vertical completions in the area (e.g., Renegade, 1992; Amoco, 1982)
- Crestone Peak (now Civitas) acquires L-BR 2019





- High resistivities in B2 & C chalks
- 10% porosities in A, B, C chalks
- PR & YM cross over illustrates “brittle” zones
- Chalks high in carbonate content
- Marls less carbonate & more clay and QFM
- GR log TOC suggests higher TOC in marl beds

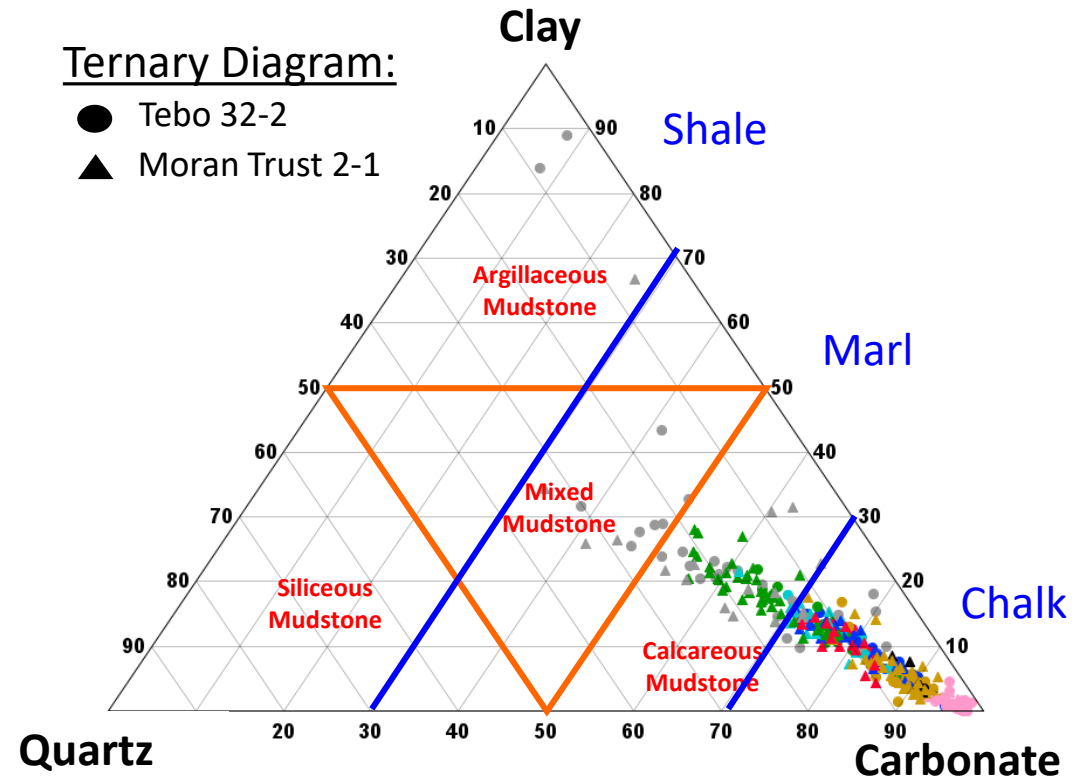
# XRD Analysis



## Ternary Diagram:

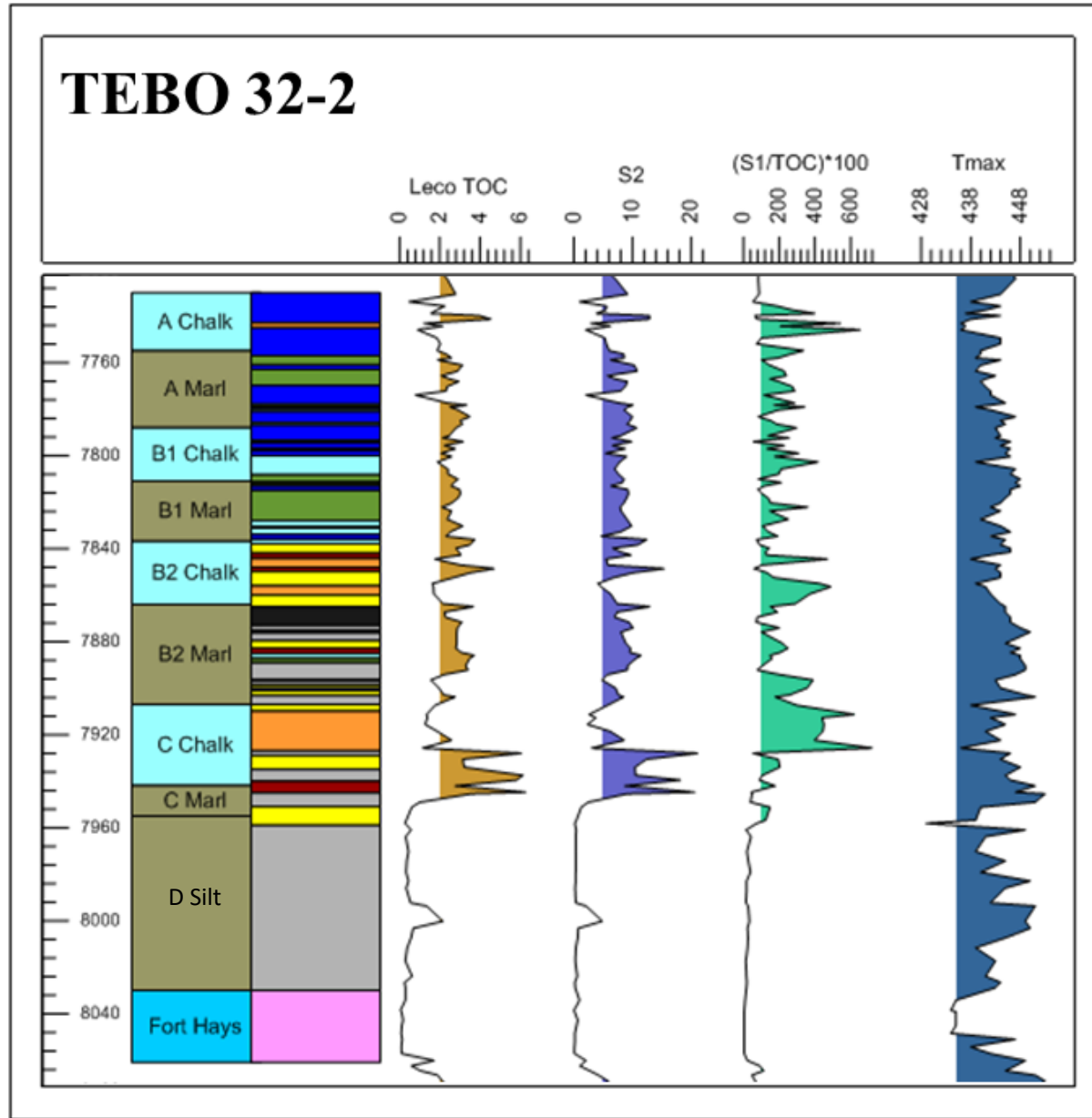
● Tebo 32-2

▲ Moran Trust 2-1



- 1. Laminated to massive light grey pellet-rich marly chalk
- 2. Laminated to massive dark grey pellet-rich marly chalk
- 3. Laminated to massive, well-preserved pellet-dominated chalky marl
- 4. Laminated to wavy, low preserved dark grey pelleted chalky marl
- 5. Bioturbated to laminated foram-rich, light grey marly chalk
- 6. Massive to laminated foram-rich marl
- 7. Foram-inoceramid-dominated marly chalk
- 8. Bioturbated, foram-rich grey chalk
- 9. Bioturbated, foram-rich chalk

# Source Quality and Maturity Evaluation



## Organic Richness (TOC)

- Highest in the C Chalk and C Marl
- Range 0.5-6.3 wt. %

## Hydrocarbon Potential (S2)

- > 5 mg/g rock considered “good to excellent”

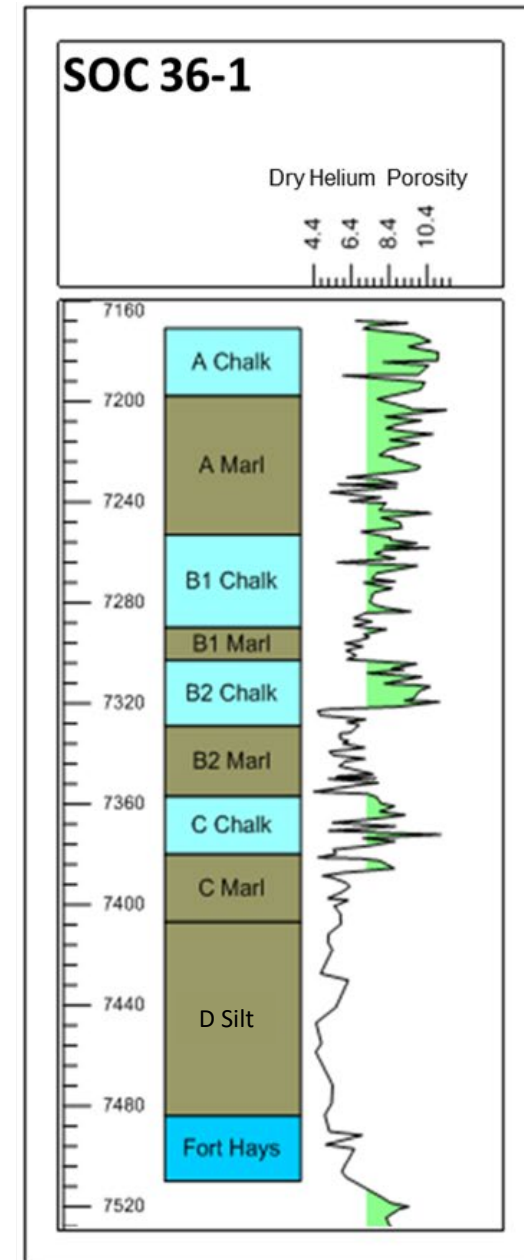
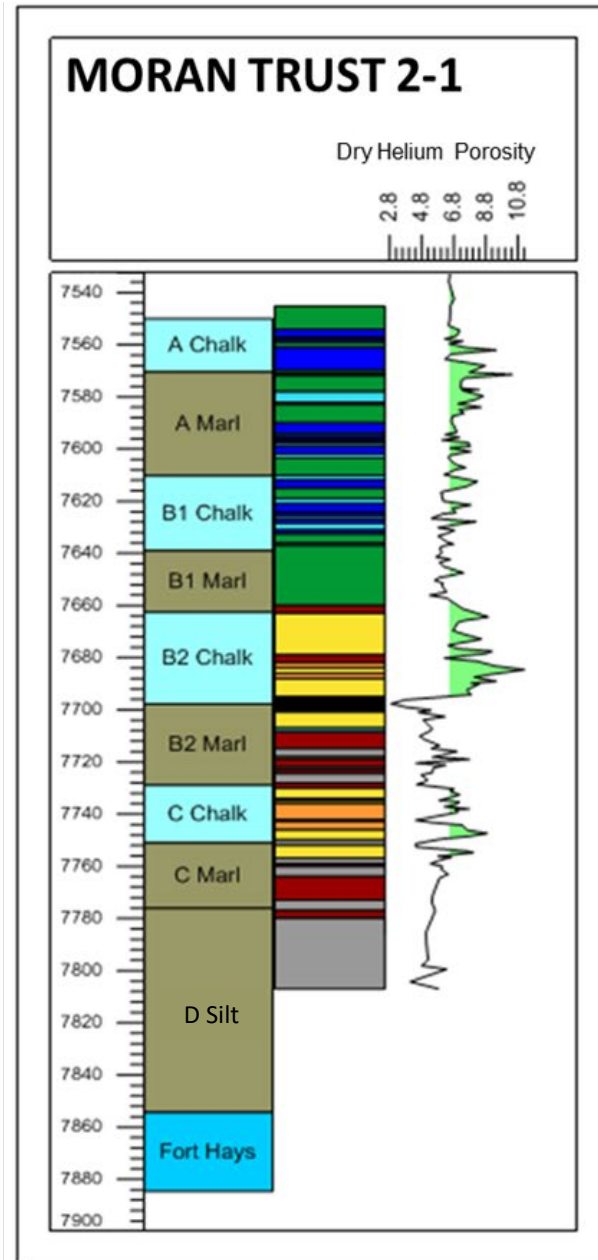
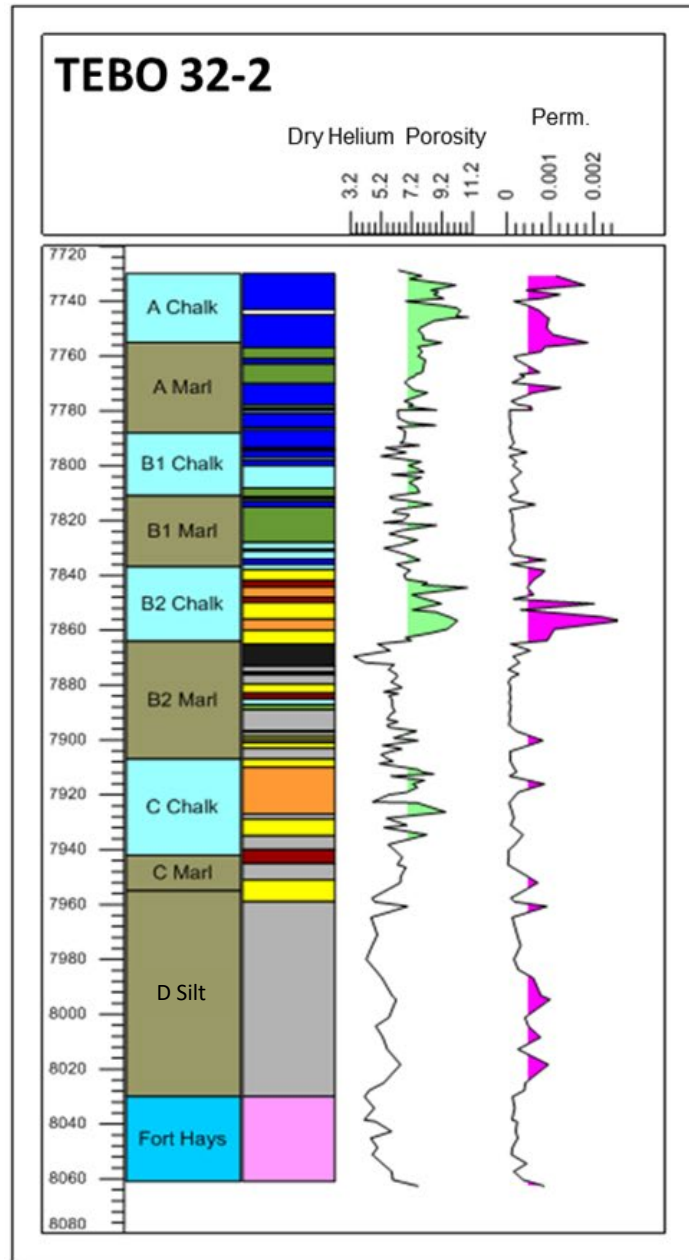
## Normalized Oil Content (S1/TOC \* 100)

- >100 mg HC/g rock indicates increasing producibility
- Highest in chalk benches

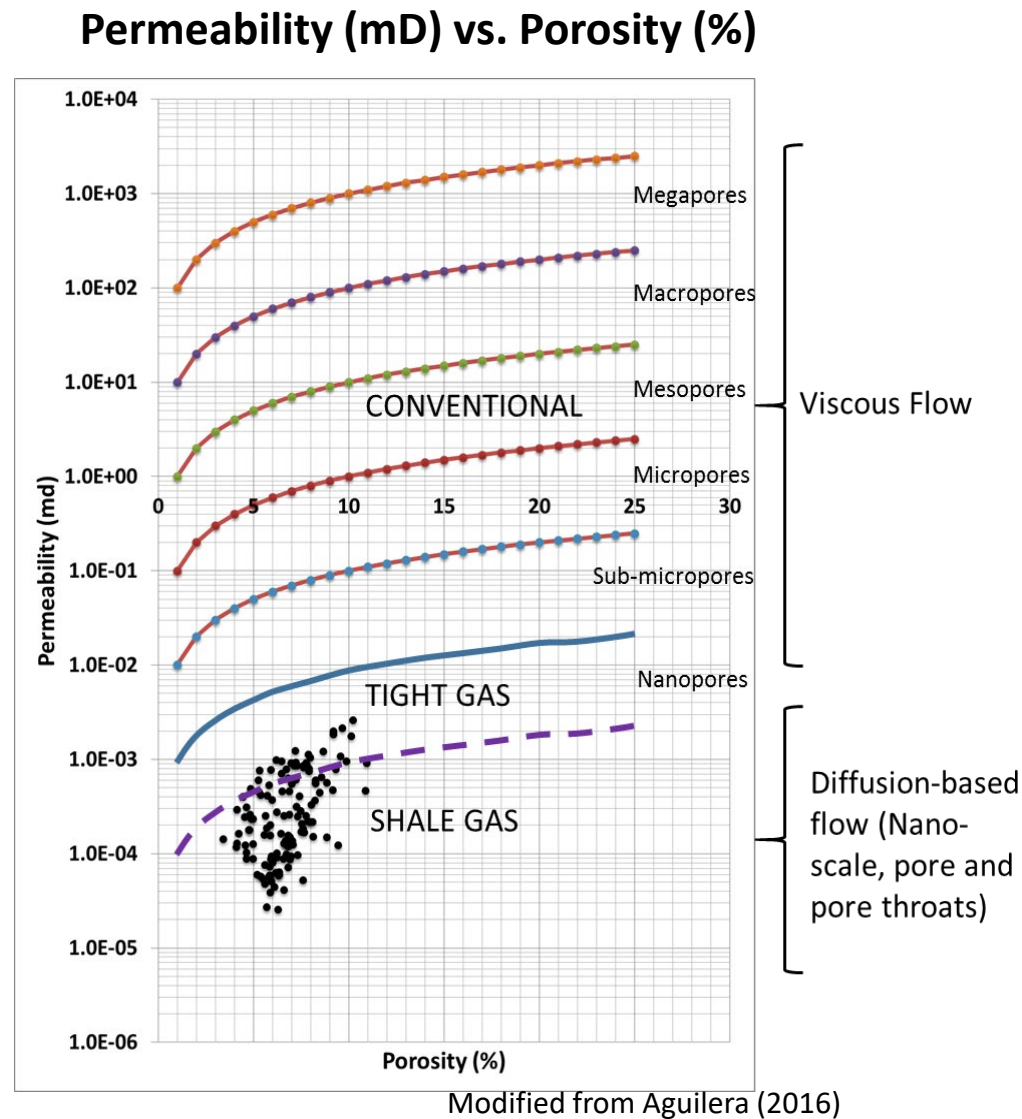
## Thermal Maturity (Tmax)

- Majority of Niobrara stratigraphy is in the oil generation window (values > 435°C)

# Permeability & Porosity Trends



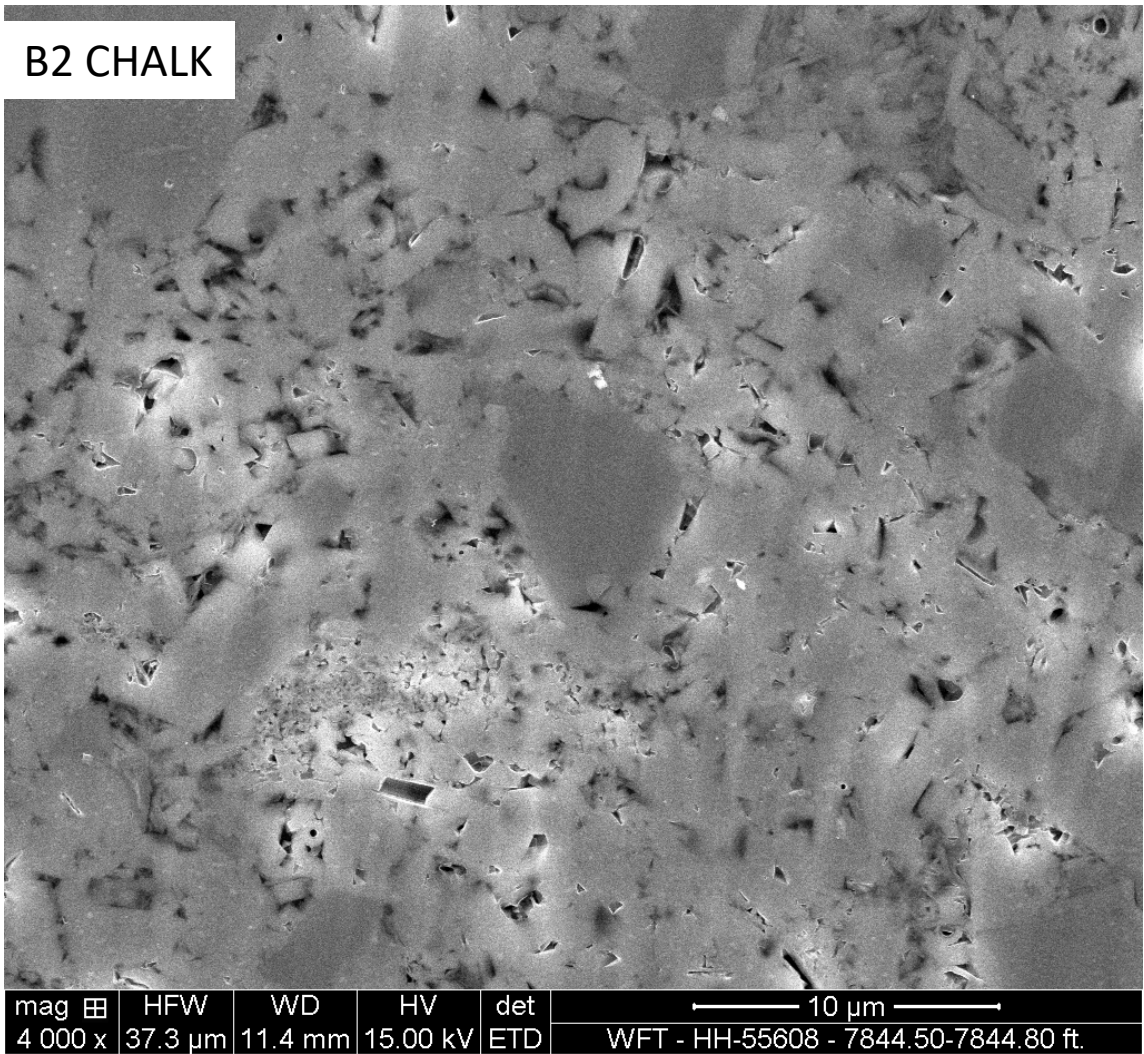
# Reservoir Quality



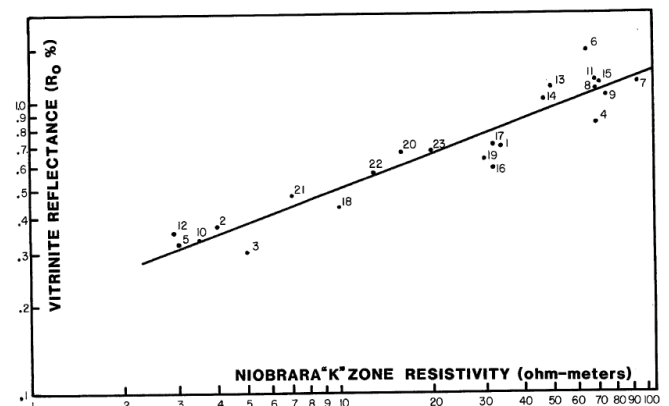
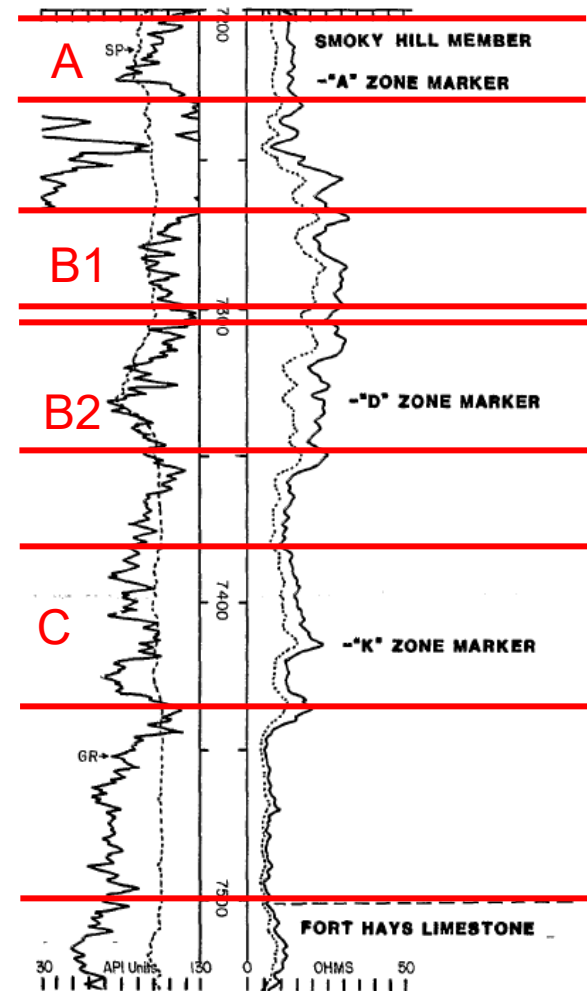
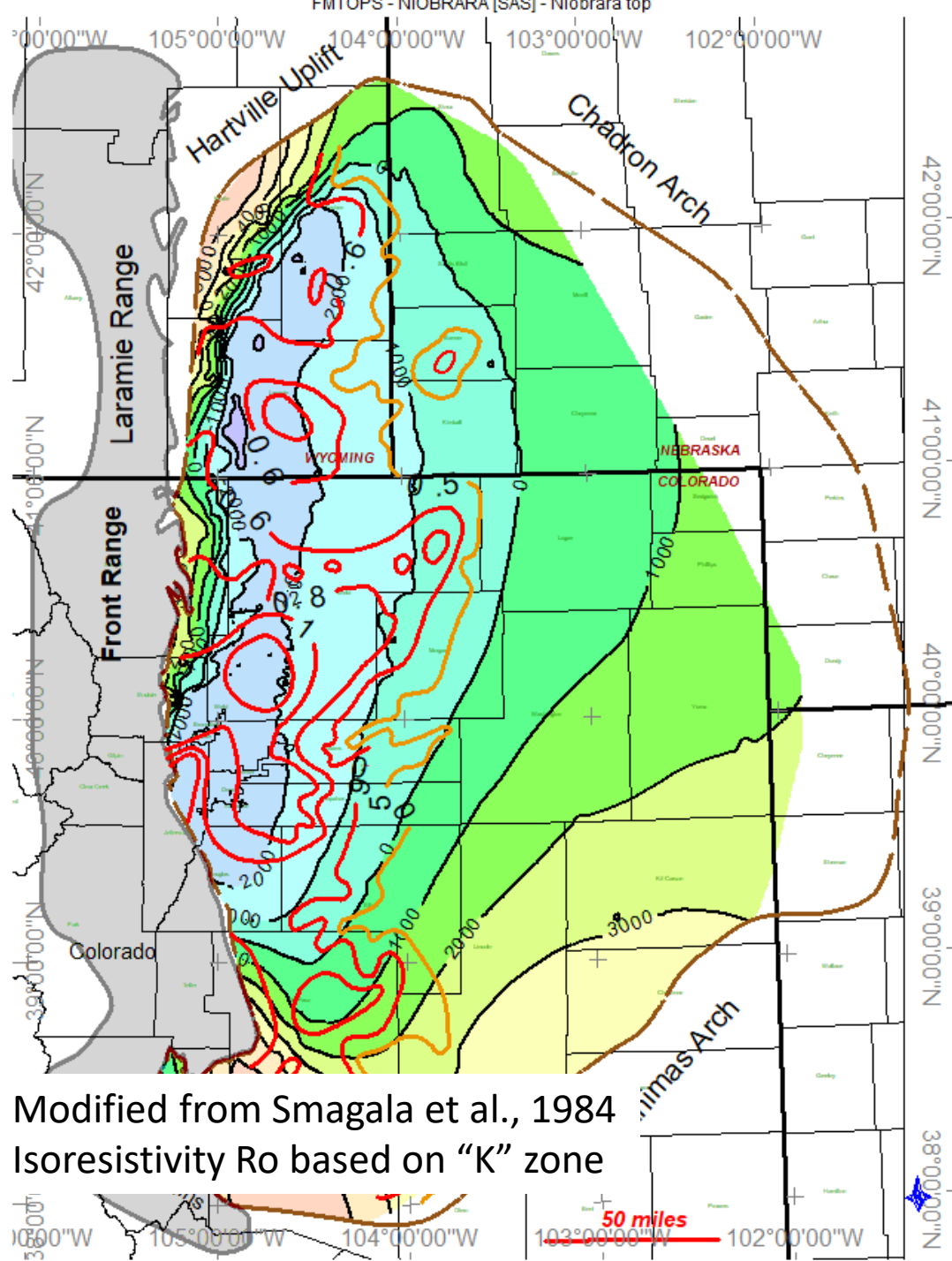
● = Data from Tebo 32-2

Secondary Electron Image

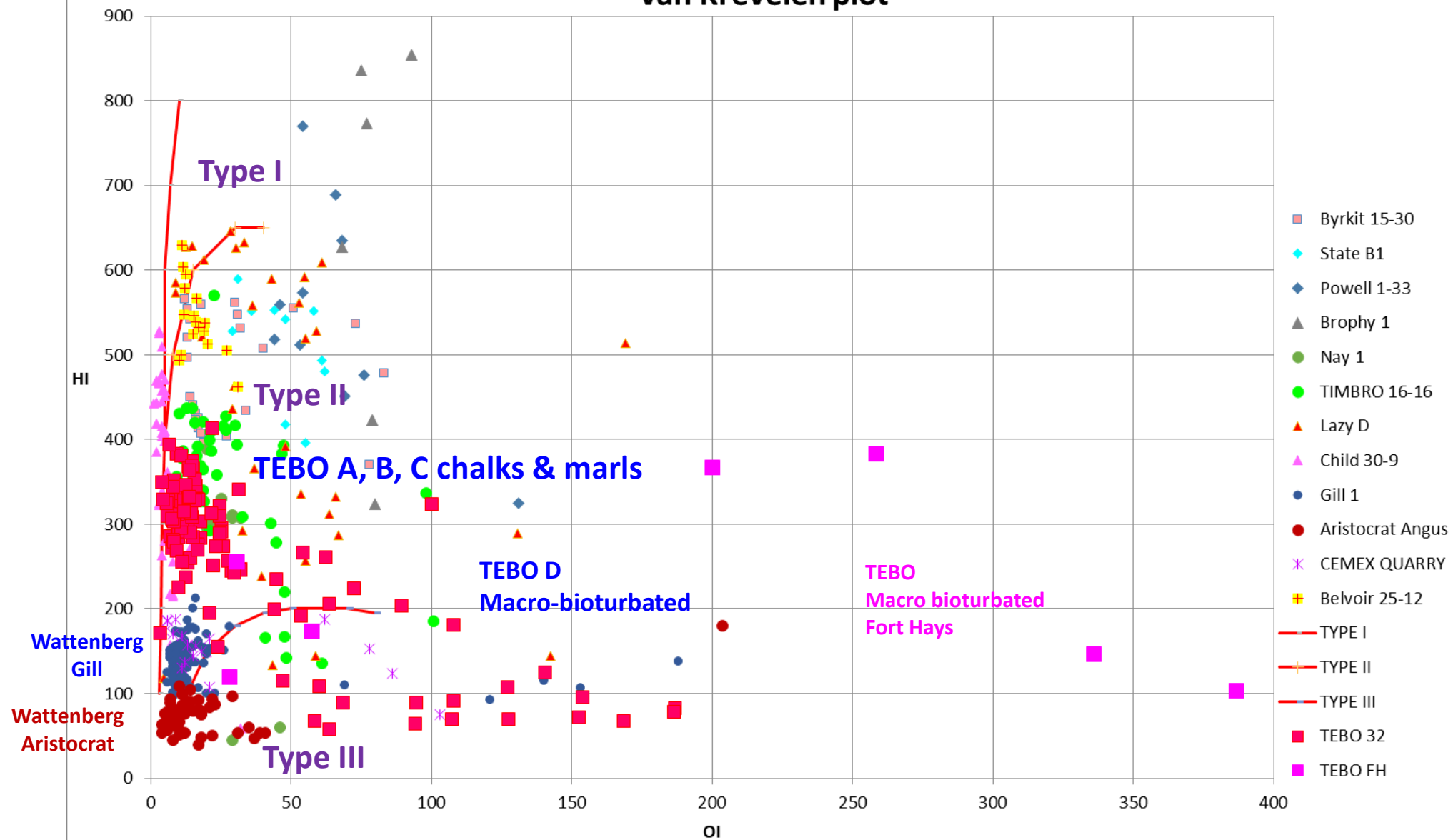
Chalky Porosity



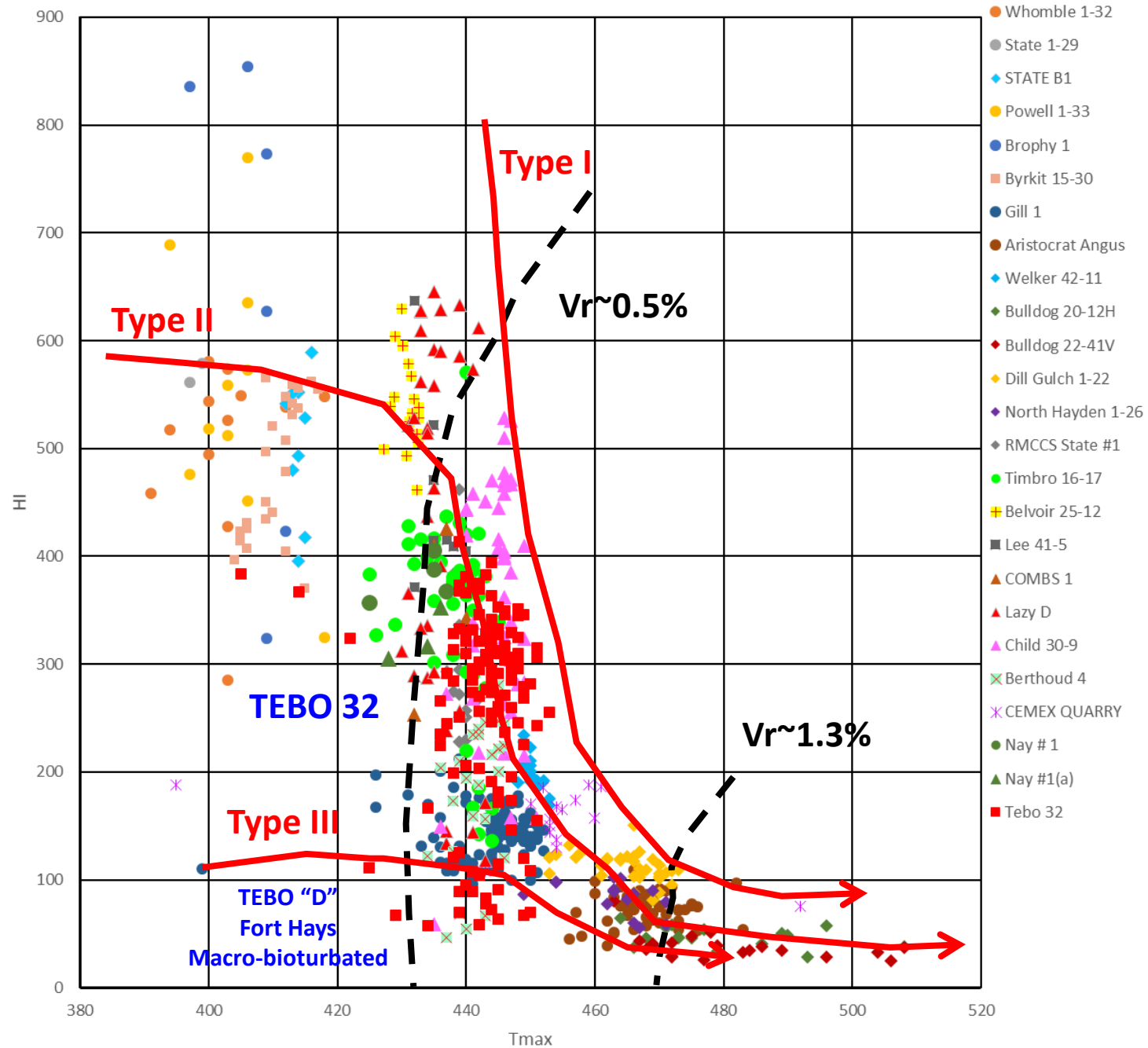
Tebo 7844.5: intergranular, intraparticle and intercrystalline porosity (coccoliths and overgrowths on coccoliths)



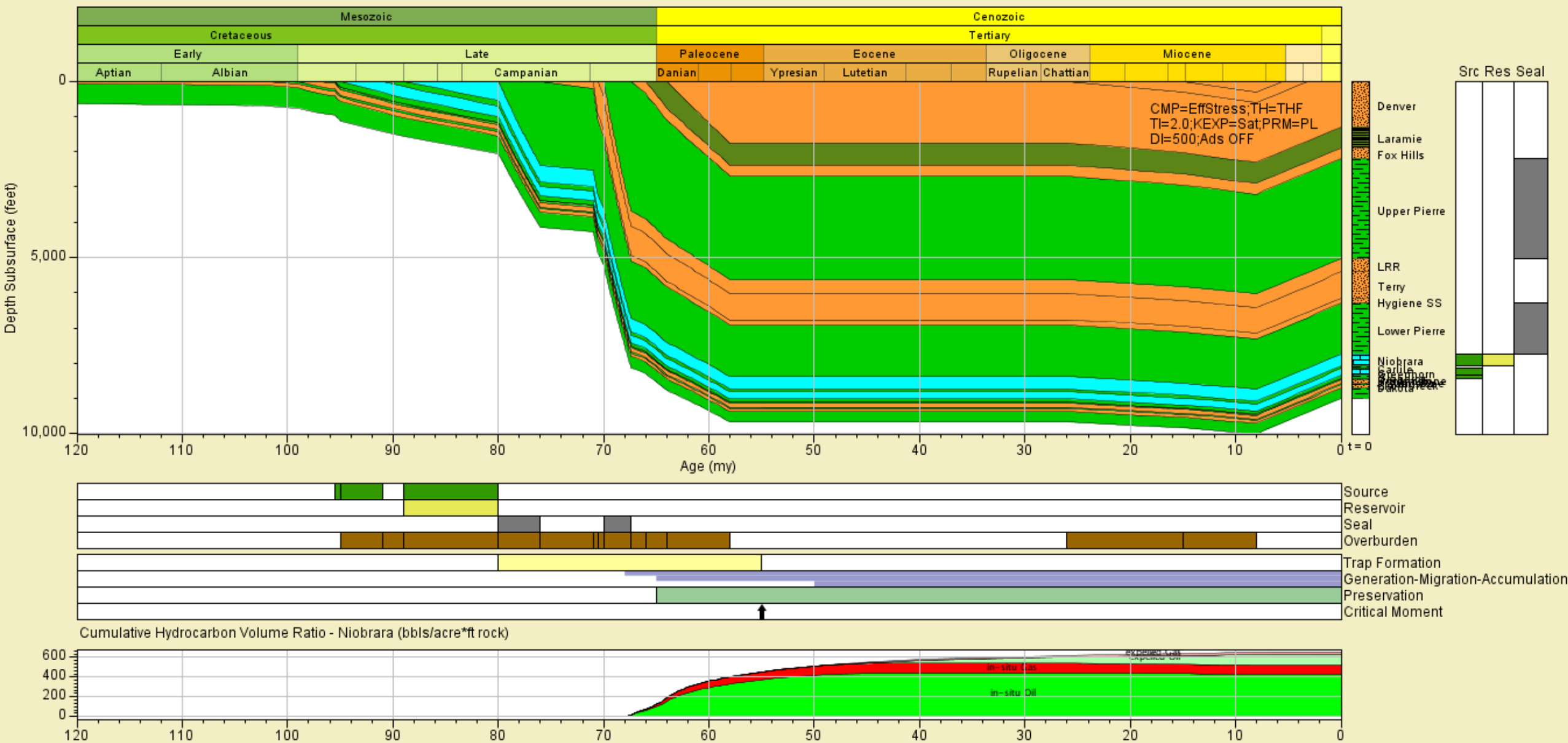
# Van Krevelen plot

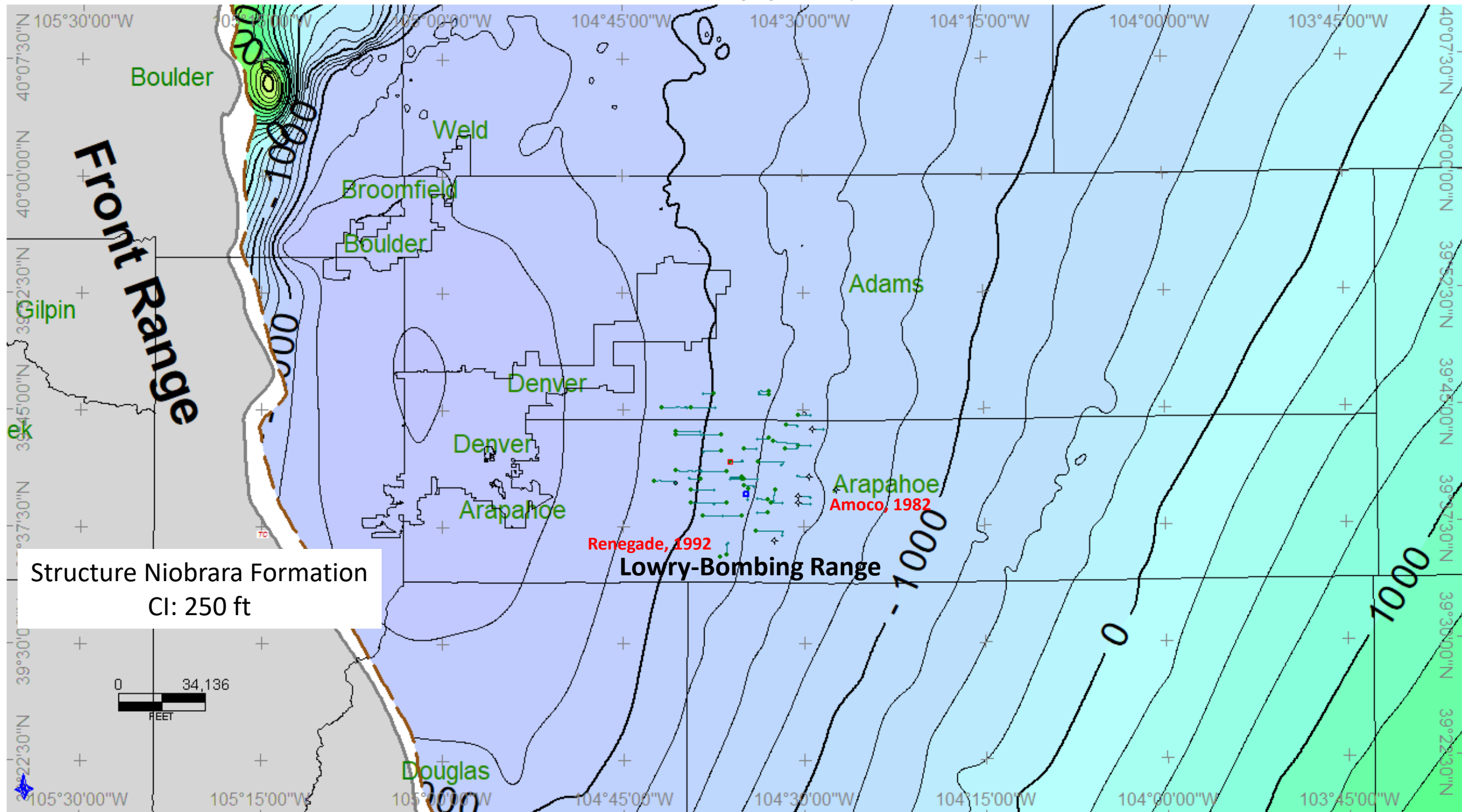


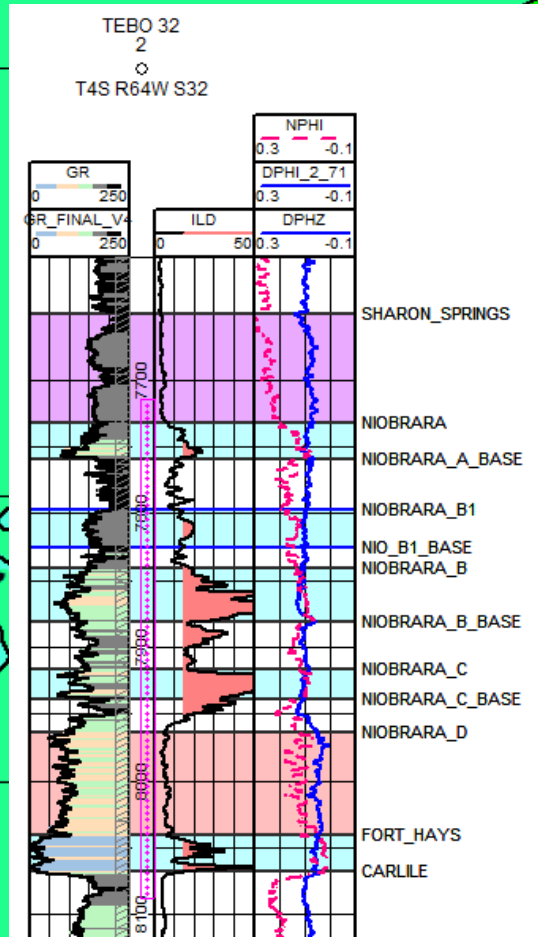
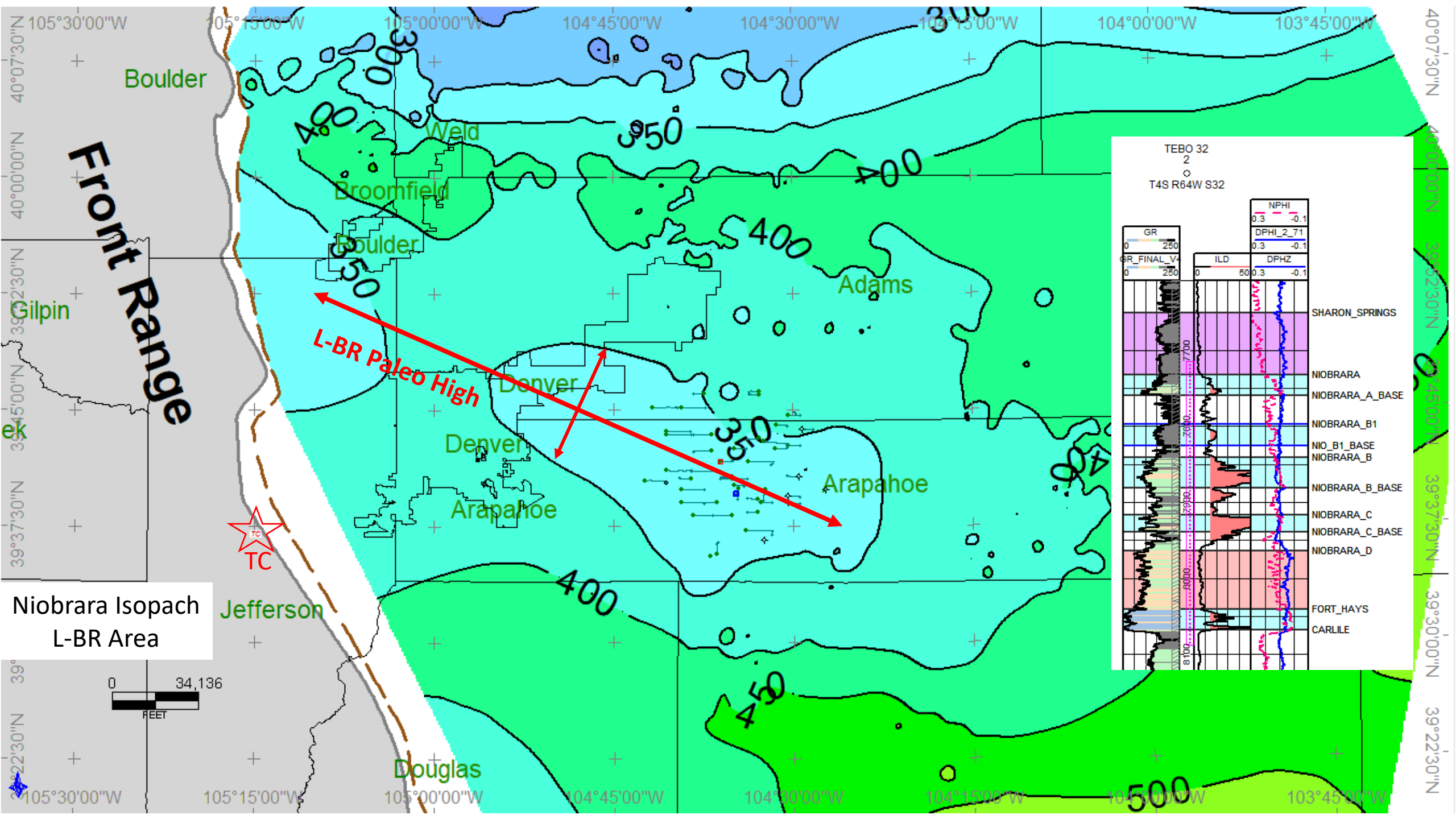
# Niobrara HI-Tmax

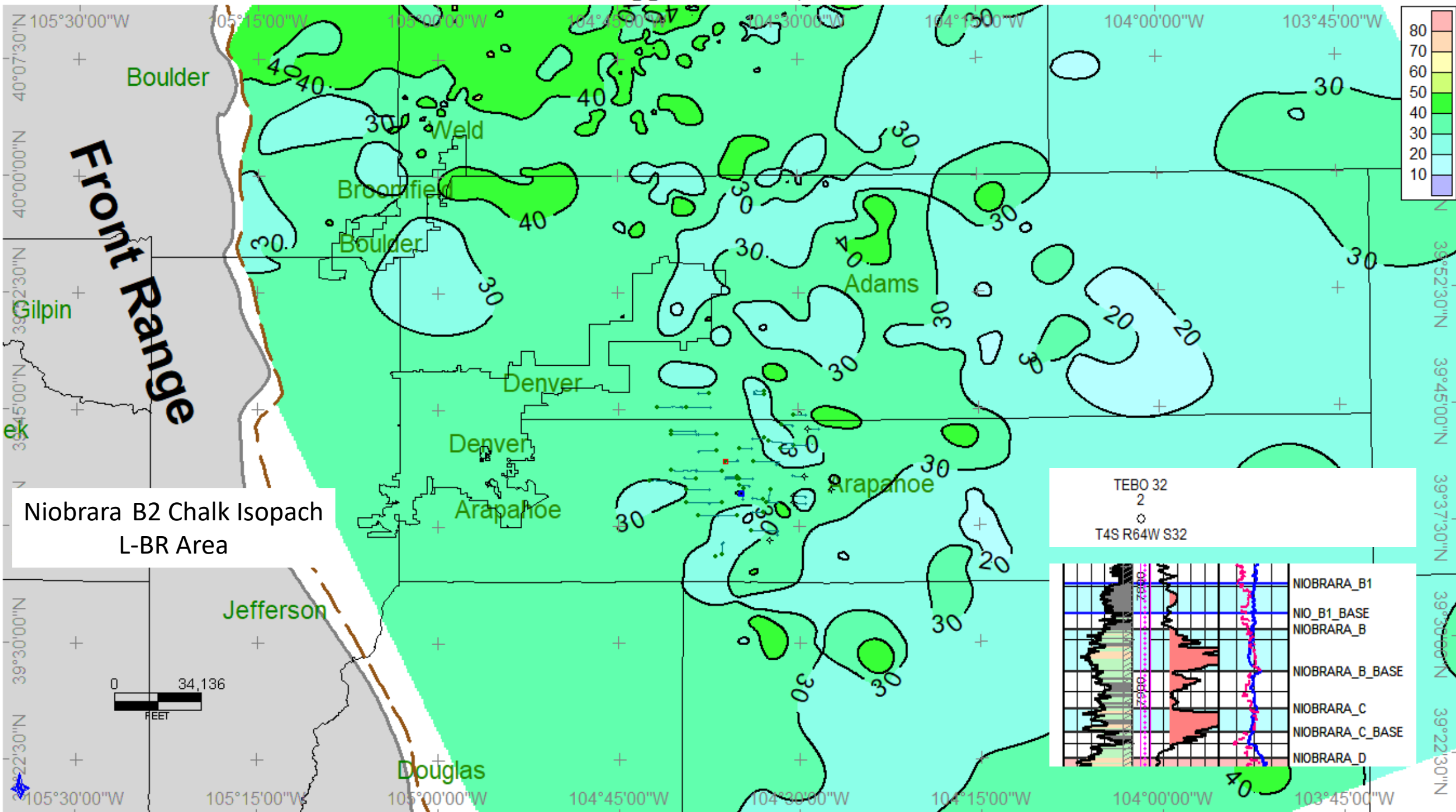


# Tebo 32-2

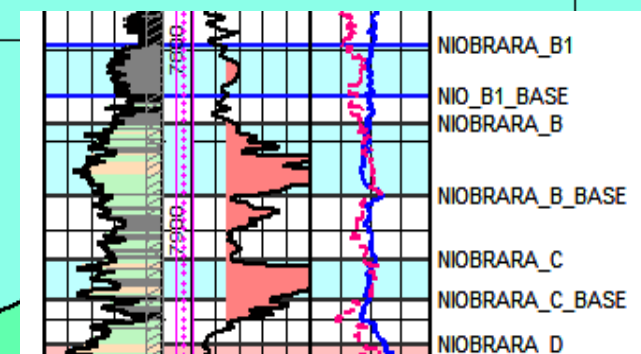


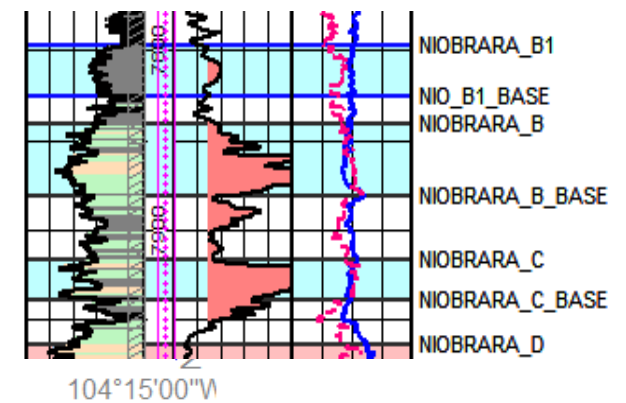
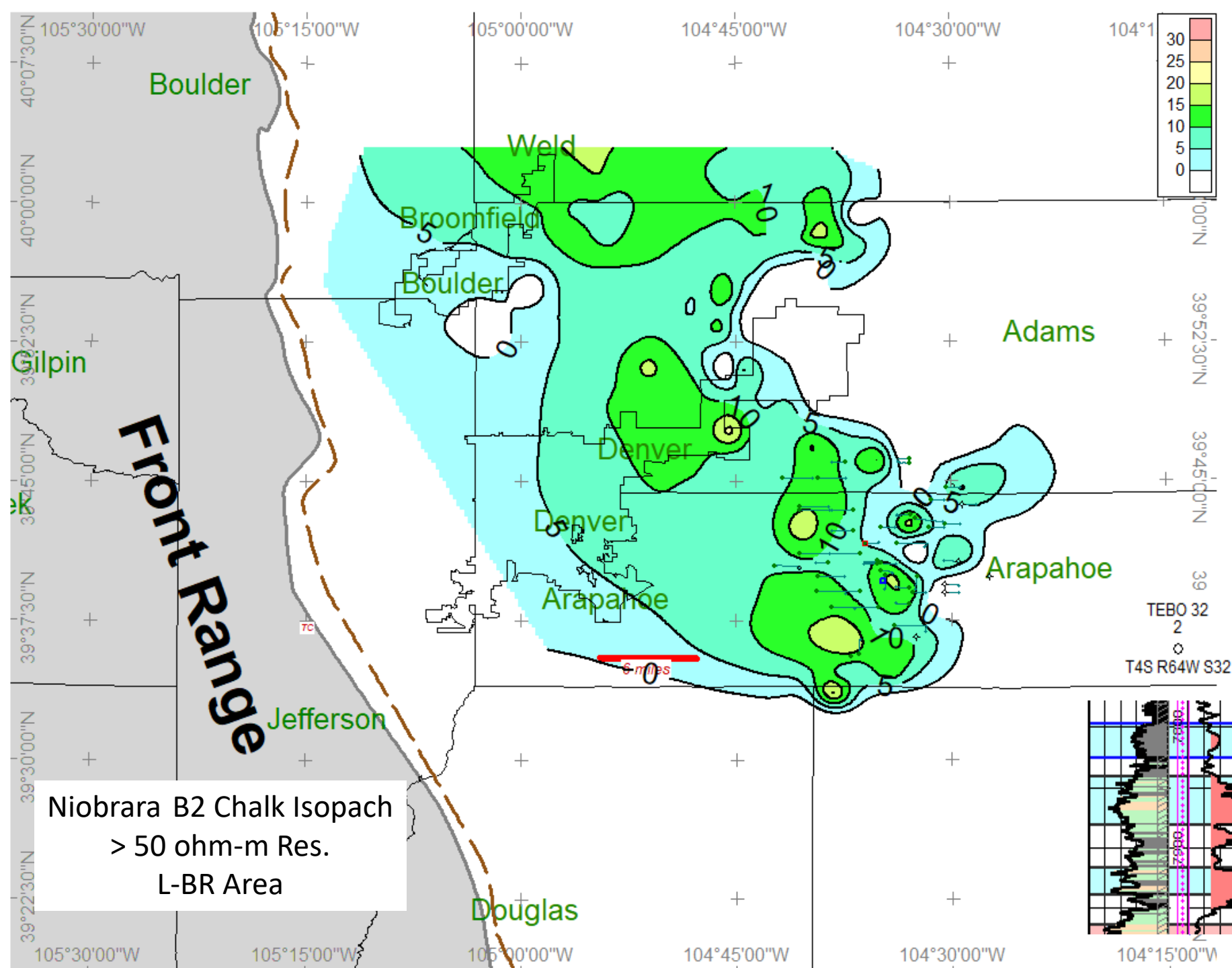


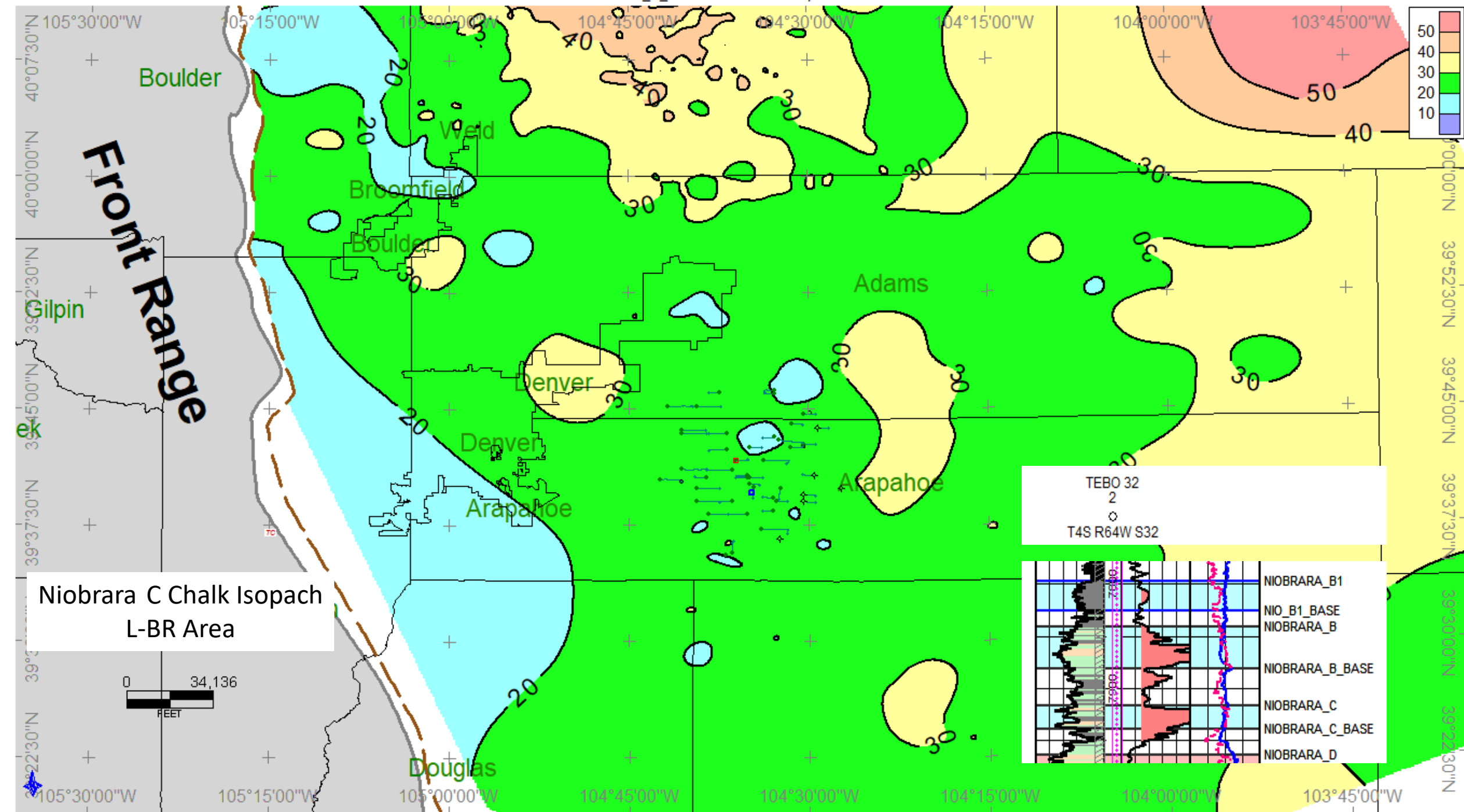




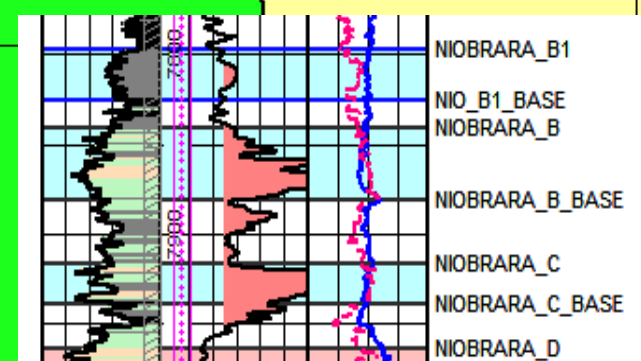
TEBO 32  
2  
T4S R64W S32

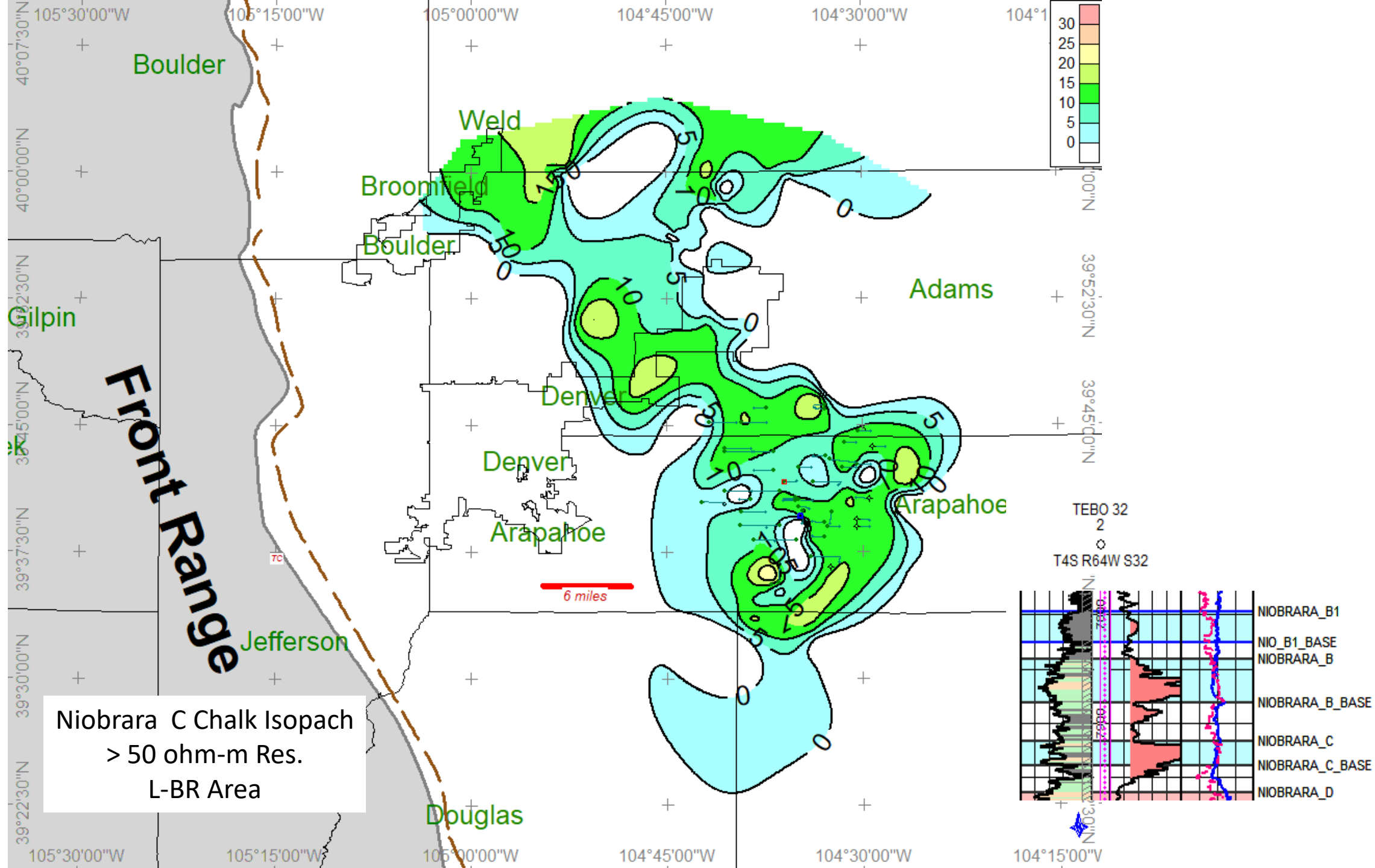






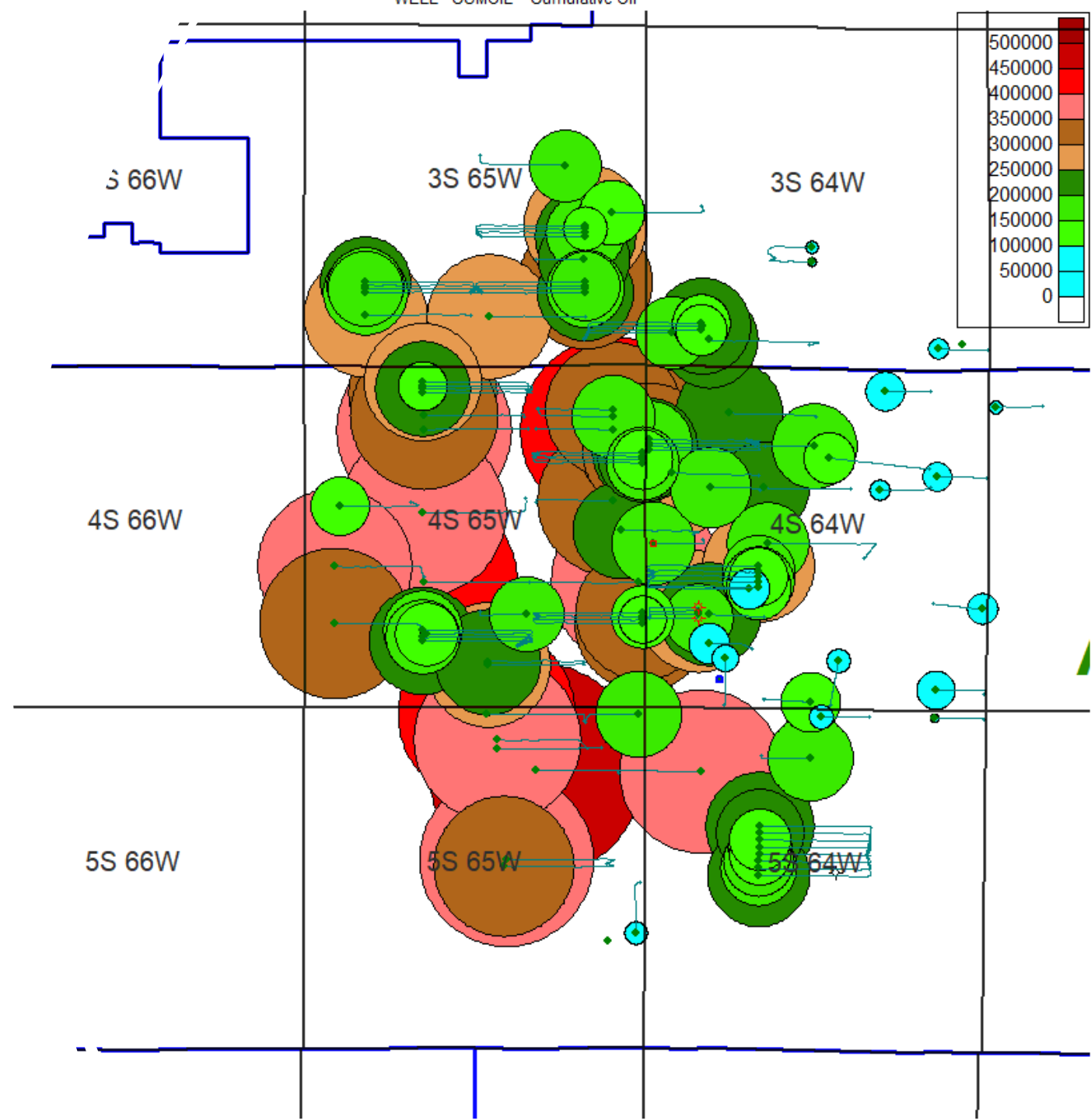
TEBO 32  
2  
T4S R64W S32





# Oil EURs Lowry-Bombing Range

- EUR Factors
  - RQ: Lithology, K, Phi, H
  - Staying in target zone
  - Fractures
  - Maturity
  - Pressure
  - Well orientation & lateral length
  - Drainage area & well spacing
  - Fracture stimulation & stages



March, 2022

● Cum Oil: 17621390

● Cum Gas: 40651805

● Cum Water: 3882280

● Monthly Volume Oil: 129206

● Monthly Volume Gas: 340408

● Monthly Volume Water: 23919

● Monthly Volume Well Count: 89

## Historical Production

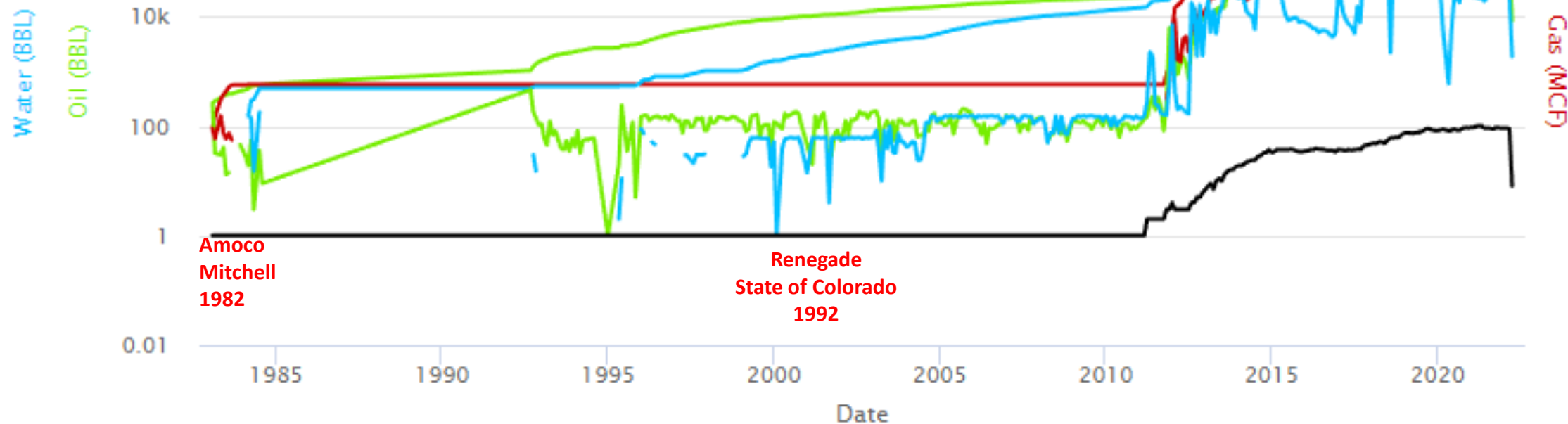
Click and drag in the plot area to zoom in

Monthly

Daily

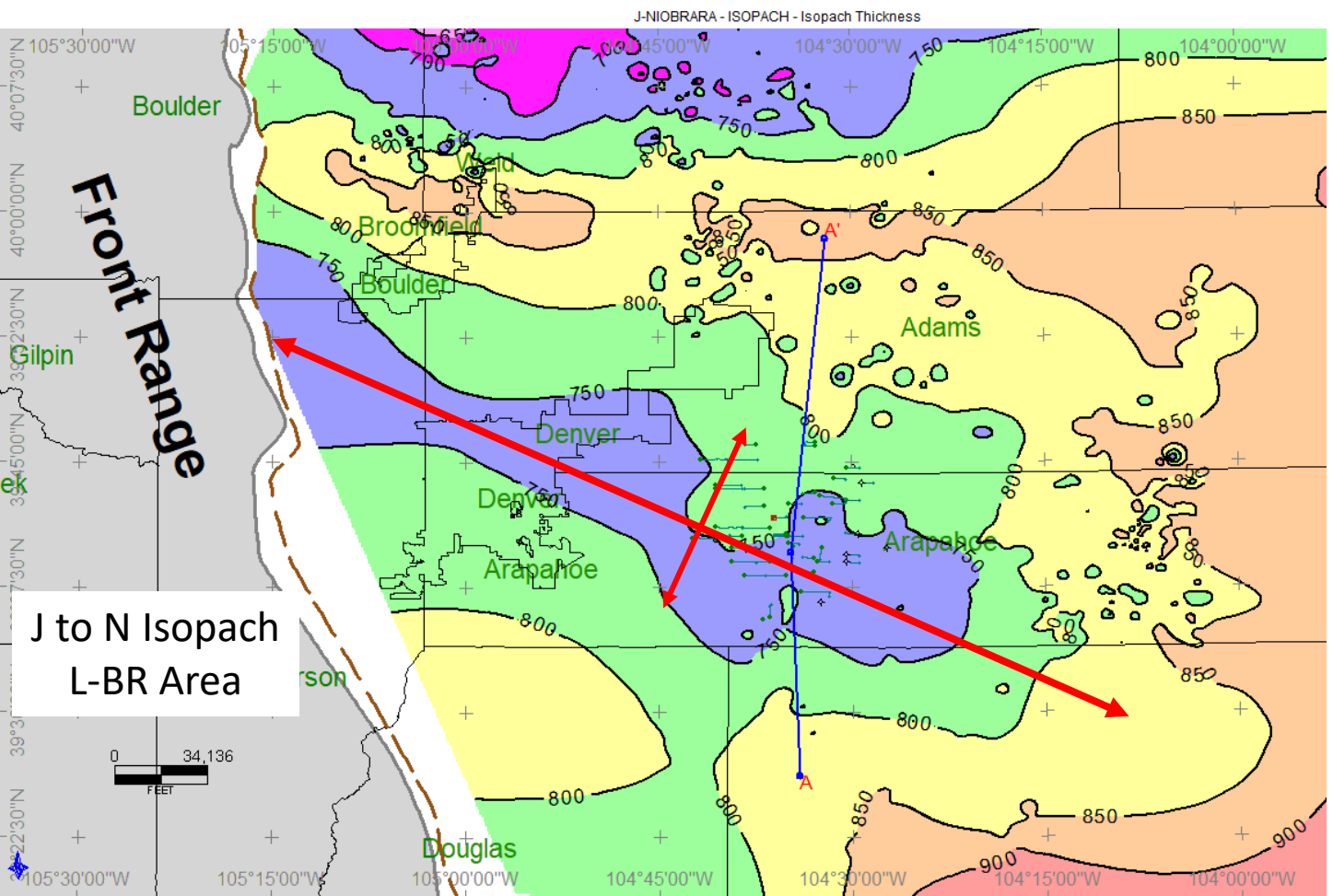
Linear

Logarithmic

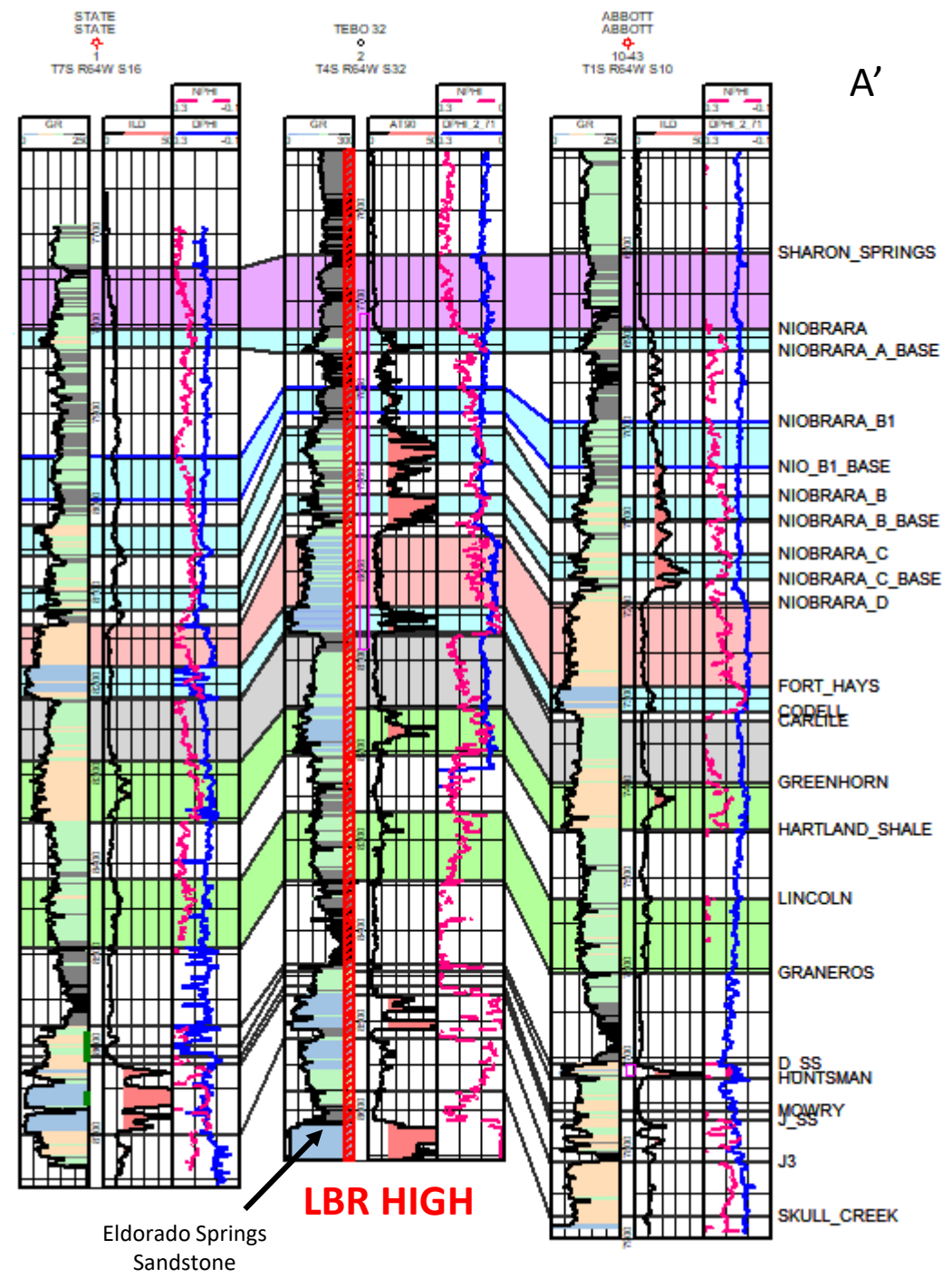


● Cum Oil ● Cum Gas ● Cum Water ● Oil ● Gas ● Water ● Well Count

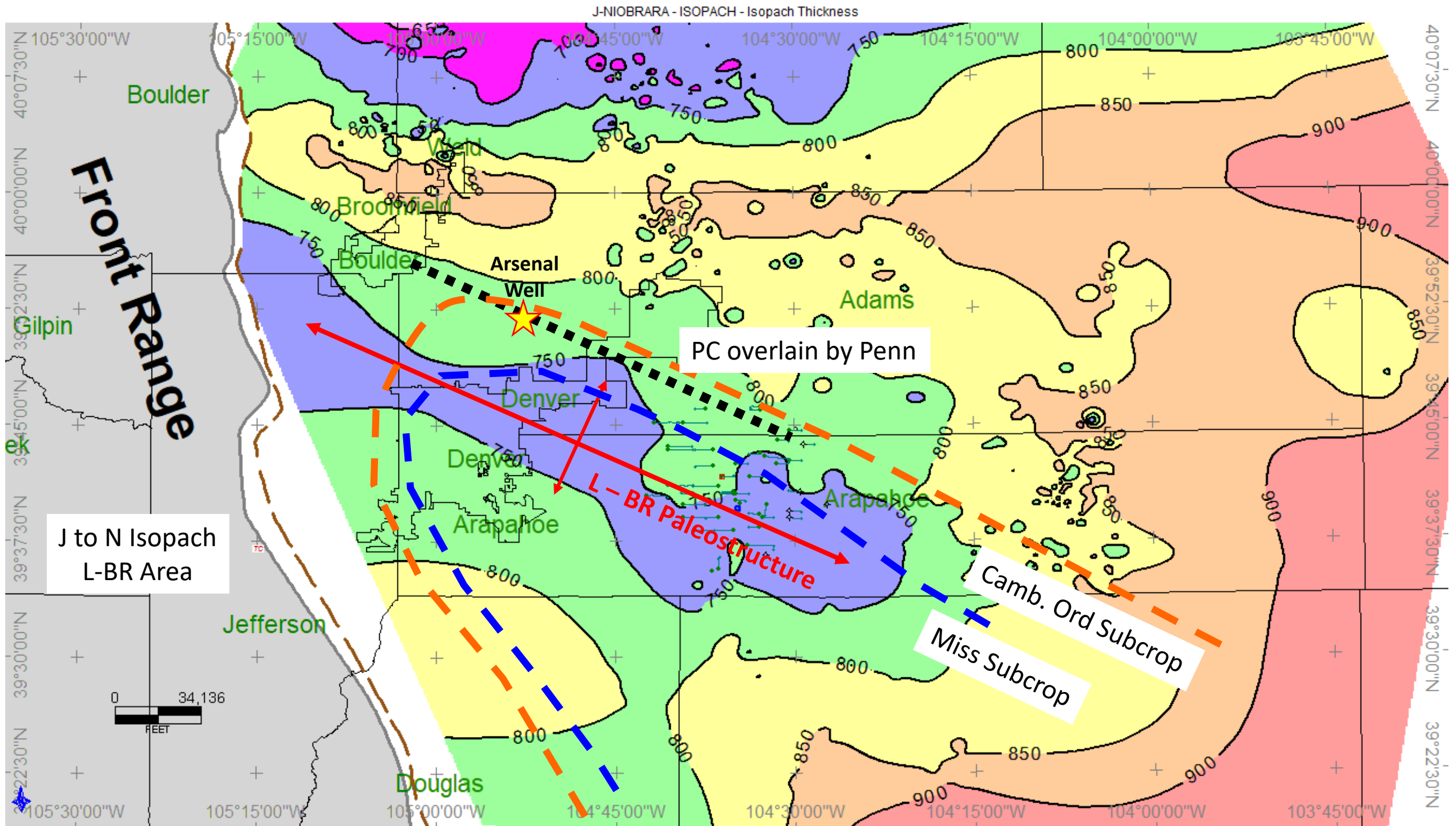




A



A'



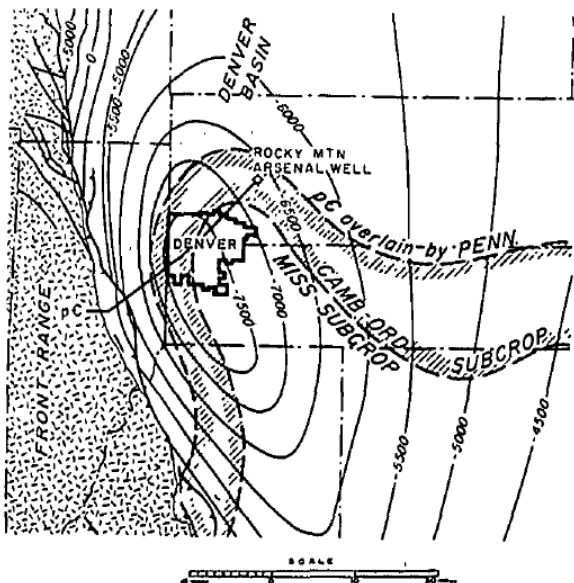
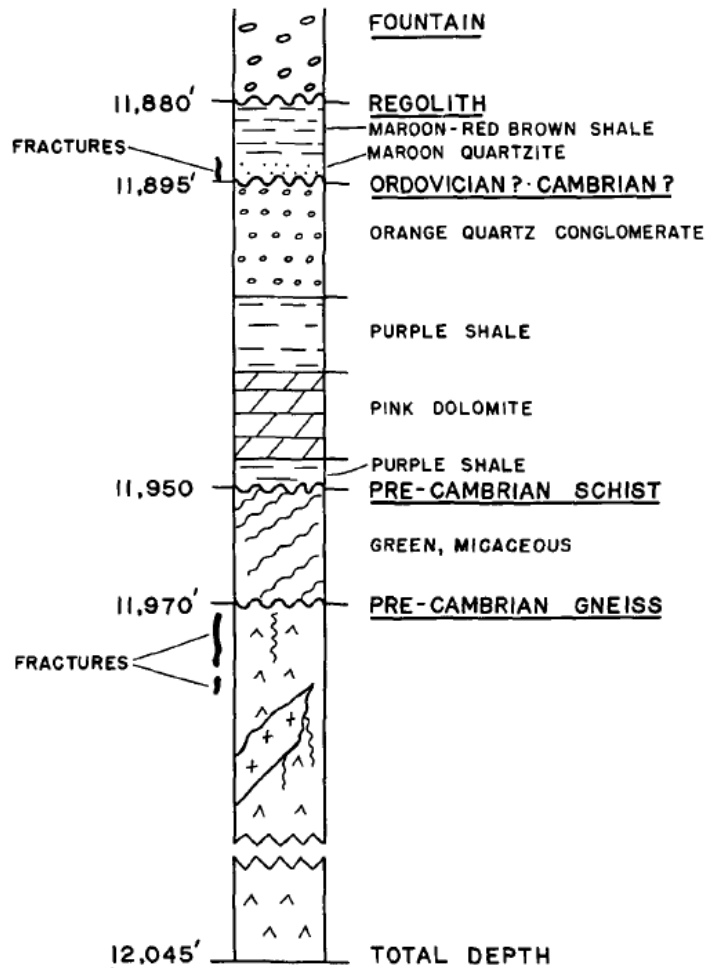
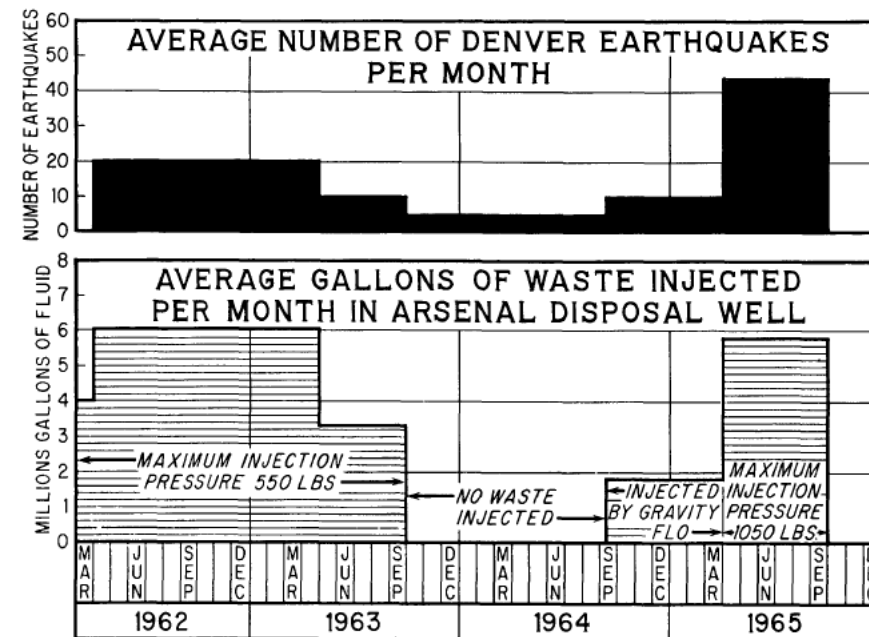


Figure 1. Structural map of a portion of the Denver-Julesburg Basin (after Anderman and Ackman, 1963), showing the location of the Rocky Mountain Arsenal well.



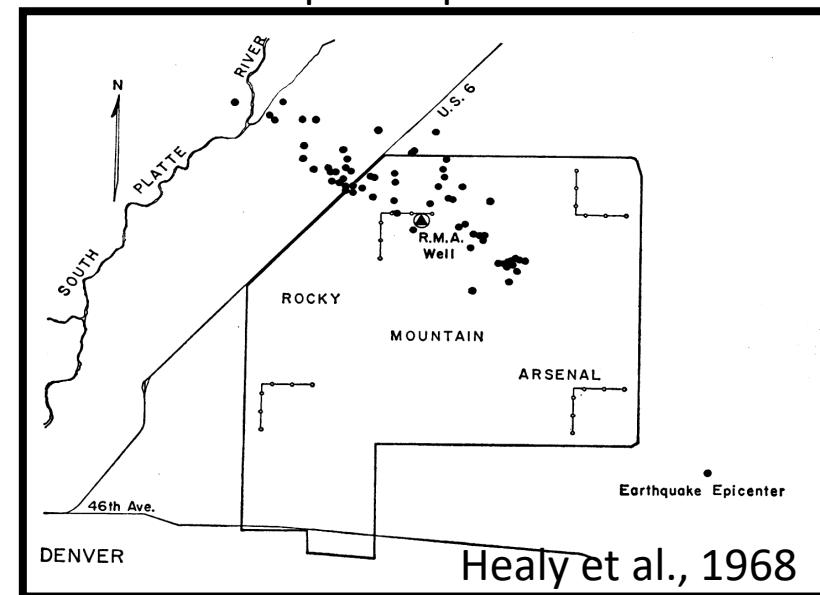
Evans, 1966



### The Denver Earthquakes:

- ◆ Disposal of waste fluid
- ◆ Arsenal well drilled in 1961
- ◆ Injection of contaminated wastewater began in 1962
- ◆ 3.6 million bbls fluid injected
- ◆ 710 earthquakes 1962-1965
- ◆ David Evans in 1965 showed a relationship between volumes of fluid injection and frequency of earthquakes
- ◆ Fluid injection increased pore pressure and reduced frictional resistance to faulting
- ◆ Magnitude 0.7-4.3

### Earthquake Epicenters





A  
South

STATE  
STATE



1

T7S R64W S16

TEBO 32



2

T4S R64W S32

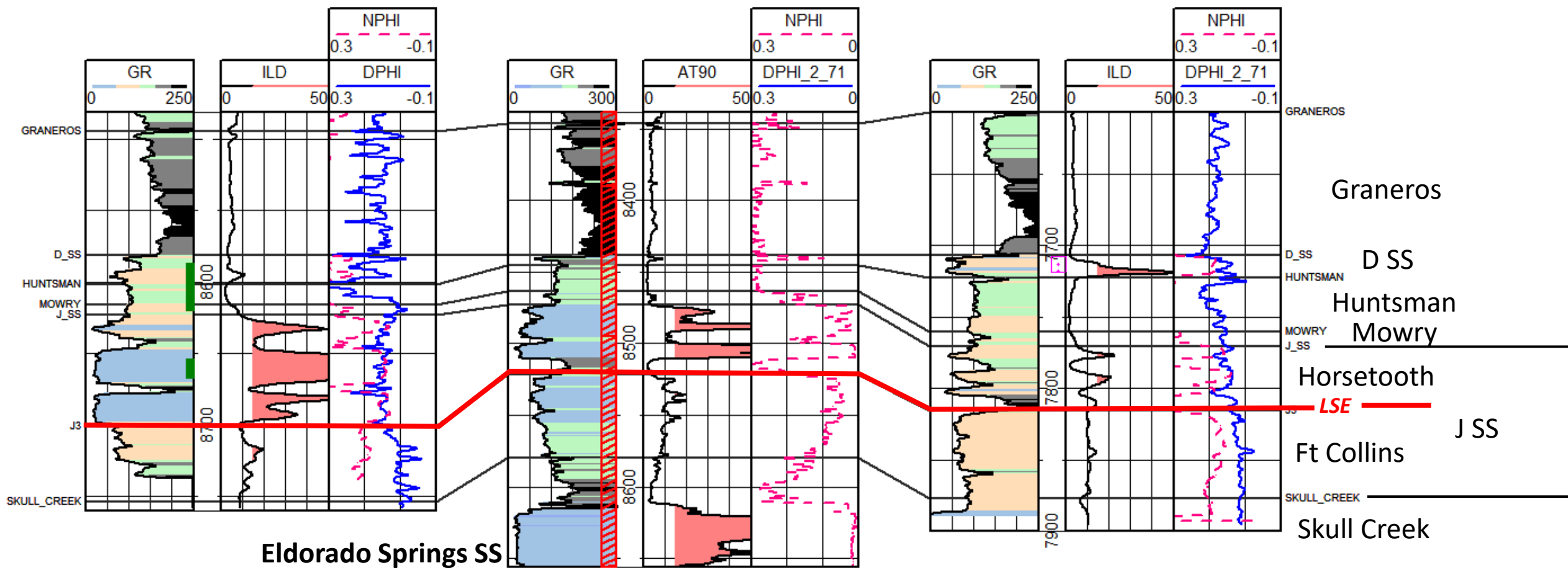
ABBOTT  
ABBOTT

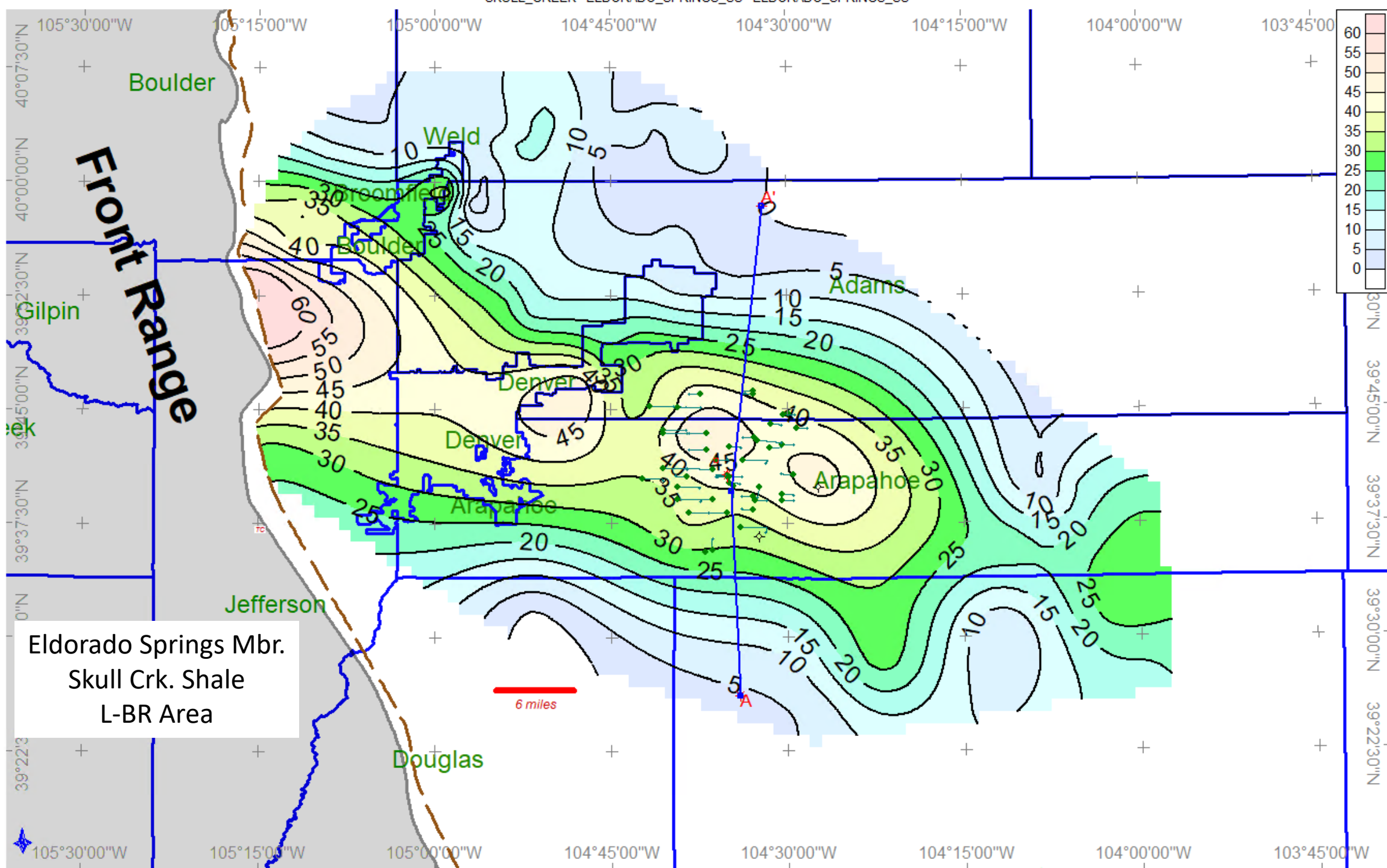


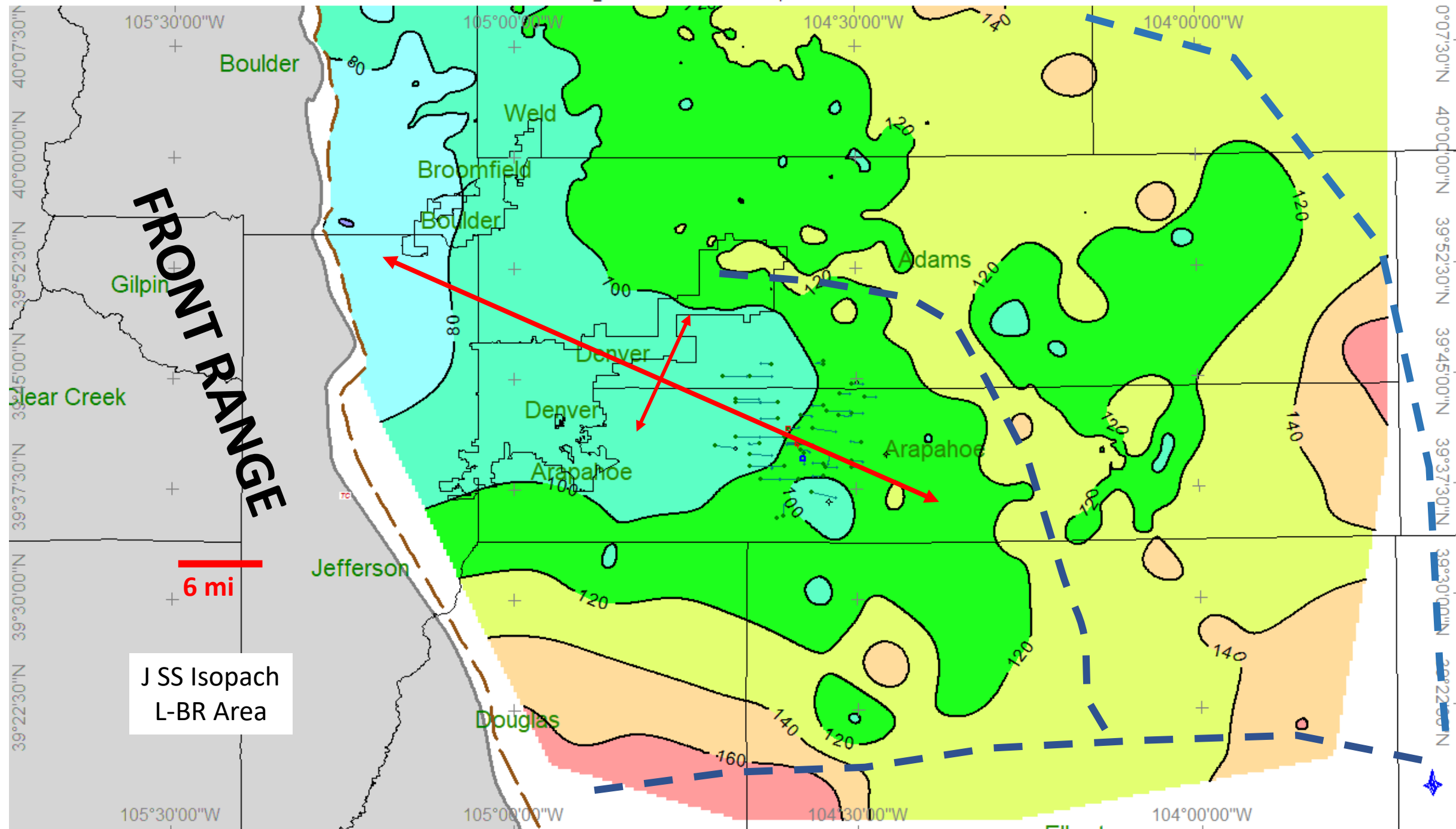
10-43

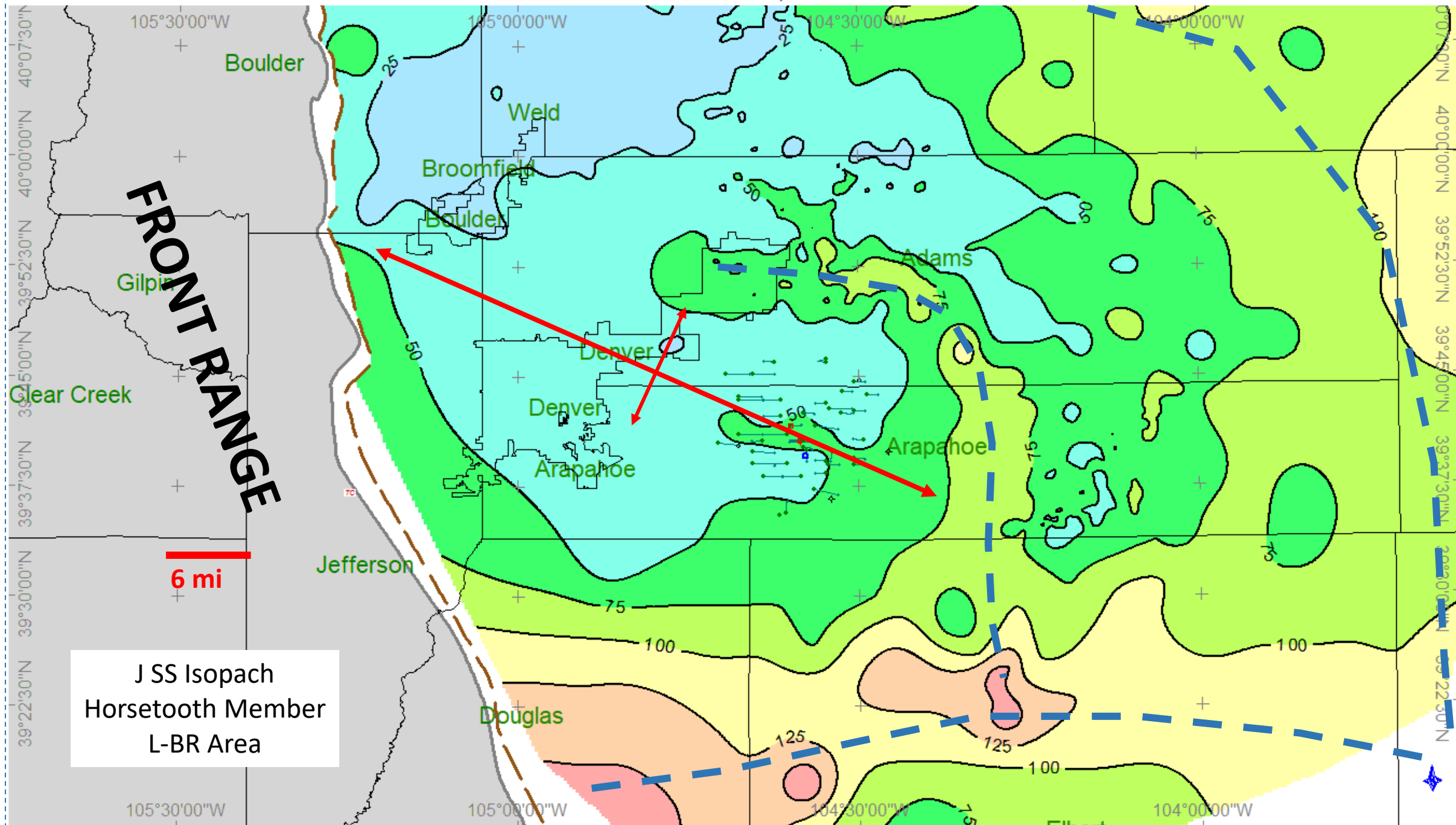
T1S R64W S10

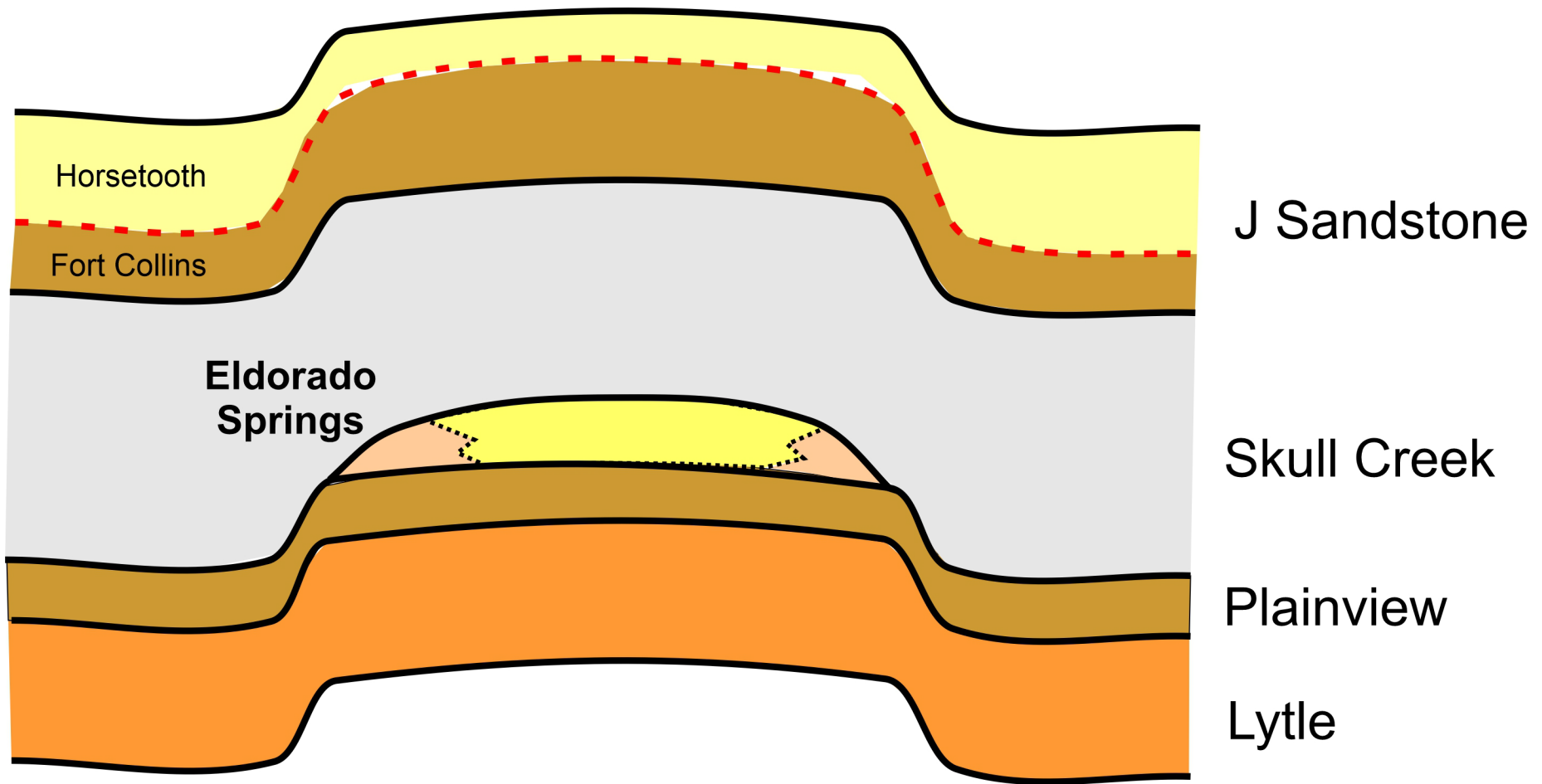
A'  
North



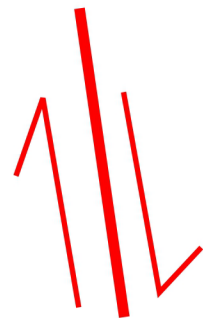




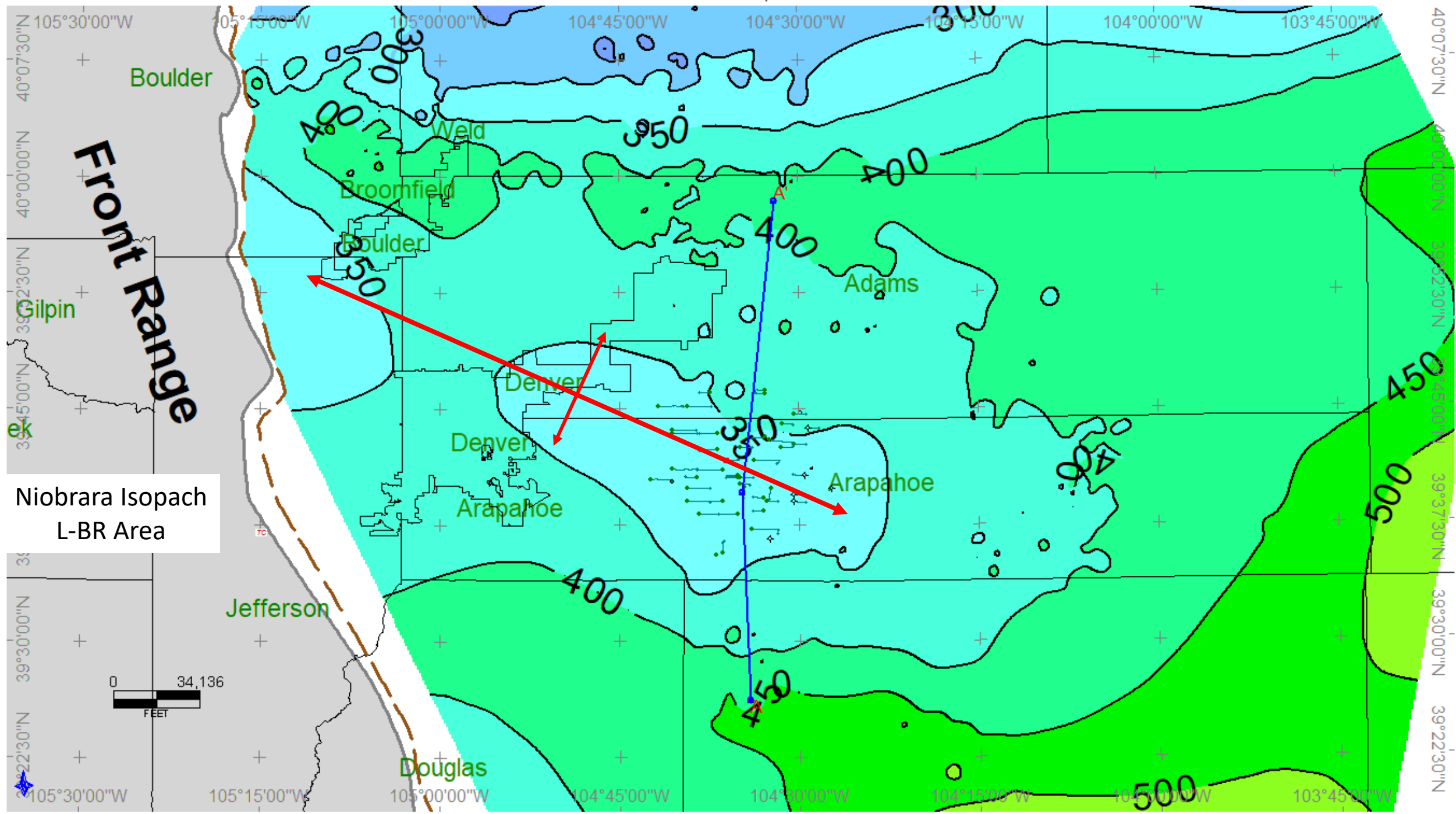




***L-BR  
Paleostucture***



**Sketch  
Not to Scale**



# Summary

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  - Most unconventional Niobrara production located on paleostructures
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  - Lower Paleozoic thickness patterns
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# Other Potential

- CCS Lyons, Entrada
- Geothermal Lyons, Entrada

# Special Thanks

- ConocoPhillips: cores and data
- MUDTOC Niobrara students

